

Albany ✓ *Q*
New York State Museum Bulletin *11*
N82

Entered as second-class matter November 27, 1915, at the Post Office at Albany, N. Y.,
under the act of August 24, 1912

Published monthly by The University of the State of New York

Nos. 223, 224 ALBANY, N. Y. *221* July-August 1919 *no. 223-224*

The University of the State of New York
New York State Museum

JOHN M. CLARKE, Director

THE MINERAL RESOURCES OF THE STATE
OF NEW YORK

BY

DAVID H. NEWLAND

	PAGE		PAGE
Introduction.....	5	Manganese ore.....	143
Mineral production of New		Marl.....	145
York.....	9	Mica.....	149
General features of the geology of		Millstones.....	154
New York and the distribution		Mineral paints.....	156
of the mineral resources.....	12	Mineral waters.....	158
Natural limitations of mining in		Molybdenite.....	163
New York State.....	23	Natural gas.....	165
Apatite.....	26	Peat.....	197
Arsenical ore.....	28	Petroleum.....	203
Asbestos.....	30	Pyrite.....	209
Barytes.....	33	Quartz.....	218
Carbon dioxide.....	35	Salt.....	221
Cement.....	37	Sand and gravel.....	235
Clay materials.....	47	Slate.....	242
Diatomaceous earth.....	64	Stone.....	247
Emery.....	66	Granite.....	250
Feldspar.....	69	Limestone.....	255
Fluorite.....	77	Marble.....	269
Fuller's earth.....	78	Sandstones.....	272
Garnet.....	79	Trap.....	279
Graphite.....	85	Strontium.....	281
Gypsum.....	91	Talc.....	283
Iron ore.....	101	Zinc.....	296
Lead.....	140	Index.....	309

ALBANY

THE UNIVERSITY OF THE STATE OF NEW YORK

1921

THE UNIVERSITY OF THE STATE OF NEW YORK

Regents of the University

With years when terms expire

(Revised to June 15, 1921)

1926 PLINY T. SEXTON LL.B. LL.D. *Chancellor Emeritus* Palmyra

1927 ALBERT VANDER VEER M.D. M.A. Ph.D. LL.D.

Chancellor Albany

1922 CHESTER S. LORD M.A. LL.D. *Vice Chancellor* Brooklyn

1924 ADELBERT MOOT LL.D. - - - - - Buffalo

1925 CHARLES B. ALEXANDER M.A. LL.B. LL.D.

Litt.D. - - - - - Tuxedo

1928 WALTER GUEST KELLOGG B.A. LL.D. - - - Ogdensburg

1932 JAMES BYRNE B.A. LL.B. LL.D. - - - - - New York

1929 HERBERT L. BRIDGMAN M.A. LL.D. - - - - - Brooklyn

1931 THOMAS J. MANGAN M.A. - - - - - Binghamton

1933 WILLIAM J. WALLIN M.A. - - - - - Yonkers

1923 WILLIAM BONDY M.A. LL.B. Ph.D. - - - - - New York

1930 WILLIAM P. BAKER B.L. Litt.D. - - - - - Syracuse

Acting President of the University and Commissioner of Education

FRANK B. GILBERT B.A. LL.D.

Assistant Commissioner and Director of Professional Education

AUGUSTUS S. DOWNING M.A. Pd.D. L.H.D. LL.D.

Assistant Commissioner for Secondary Education

CHARLES F. WHEELOCK B.S. Pd.D. LL.D.

Assistant Commissioner for Elementary Education

GEORGE M. WILEY M.A. Pd.D. LL.D.

Director of State Library

JAMES I. WYER M.L.S. Pd.D.

Director of Science and State Museum

JOHN M. CLARKE D.Sc. LL.D.

Chiefs and Directors of Divisions

Administration, HIRAM C. CASE

Archives and History, JAMES SULLIVAN M.A. Ph.D.

Attendance, JAMES D. SULLIVAN

Examinations and Inspections, AVERY W. SKINNER B.A.

Law, FRANK B. GILBERT B.A. LL.D., *Counsel*

Library Extension, WILLIAM R. WATSON B.S.

Library School, EDNA M. SANDERSON B.A. B.L.S.

School Buildings and Grounds, FRANK H. WOOD M.A.

School Libraries, SHERMAN WILLIAMS Pd.D.

Visual Instruction, ALFRED W. ABRAMS Ph.B.

Vocational and Extension Education, LEWIS A. WILSON

*The University of the State of New York
Department of Science, February 24, 1919*

*Doctor John H. Finley
President of the University*

SIR:

I transmit to you herewith and beg to recommend for publication, as a Bulletin of the State Museum, a manuscript report entitled:

The Mineral Resources of the State of New York which has been prepared by David H. Newland, Assistant State Geologist.

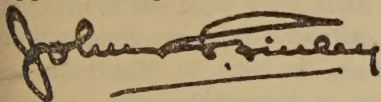
It is needless for me to emphasize the importance of a work of this kind to the intellectual and commercial interests of this State. The report is a summary of our present knowledge of what is, second only to the soil of the State, its most important natural asset. In variety, quality and quantity the mineral production and the potential mineral resources are of momentous importance to the people of the State.

Very respectfully yours

JOHN M. CLARKE

Director

Approved for publication

A handwritten signature in dark ink, appearing to read "John H. Finley", with a horizontal line drawn underneath it.

President of the University

New York State Museum Bulletin

Entered as second-class matter November 27, 1915, at the Post Office at Albany, N. Y., under the act of August 24, 1912

Published monthly by the University of the State of New York

No. 223, 224

ALBANY, N. Y.

July-August 1919

The University of the State of New York New York State Museum

JOHN M. CLARKE, Director

THE MINERAL RESOURCES OF THE STATE OF NEW YORK

BY DAVID H. NEWLAND

INTRODUCTION

This report is intended to serve the purpose of a general guide to the mineral resources of New York. It presents the principal facts regarding the character, occurrence and production of the useful minerals, with reference to particulars of the local features that bear upon their industrial utilization. It supplements and extends the information contained in the annual "The Mining and Quarry Industry of New York" which has been published as a bulletin of the New York State Museum since 1904.

The preparation of a treatise of this kind requires the cooperation of practically all who are engaged in the related industrial fields. Cordial acknowledgment is rendered by the writer to those who have assisted him by supplying information in the office or at the mine and for the many opportunities which he has enjoyed of personally inspecting new and interesting operations. The aid of many individuals has also been solicited, for which a general acknowledgment is here made. To C. A. Hartnagel has fallen the task of final supervision of the manuscript.

The need for a new and revised account of our mineral resources has been emphasized in the last year or two by the changes that have taken place in the economic relations of raw material supplies. Some materials have taken on increased importance through the

expansion of the market demands, making feasible the working of deposits hitherto considered of remote value; for others the conditions have not favored any enlargement of productive activity and even in some instances have caused a notable contraction from the normal quotas; but for nearly all it may be said that the course of economic development has been under the control of factors scarcely anticipated and whose effects will continue to be felt after the special causes themselves have been removed.

The statistical canvasses of the mineral industries for the years 1917 and 1918, which were conducted by this office in cooperation with the United States Geological Survey showed the value of the products for 1917 to have been \$51,935,094. This represented a gain of \$5,987,147, or 13 per cent, in the value as compared with that reported for 1916. In 1918 the value of the products amounted to \$54,169,287, an increase of \$2,234,193 in value over the year 1917. As shown by the statistics on following pages the increased value of the output for 1918 resulted partly from an increase in quantity of a few of the mineral products together with higher prices; and partly from the increased value of some of the products, although the quantities produced were less than in the preceding year. The values given for both the years 1917 and 1918 are new records for the mineral industry.

The products of which notice has been taken in the statistical investigations number over thirty and with few exceptions represent their first forms as they come from the mines or quarries without elaboration or manufacture, except so much as may have been necessary to put them in marketable condition. They are not inclusive of secondary products like iron and steel, ferro-alloys, aluminum, coke, sulphuric acid, alkali products of salt, artificial graphite, calcium carbide, etc., that are made from the crude ores and minerals and that in combined value far outrank the reported total for the basic materials.

Among the materials that have an important place in the list of products are iron ore, zinc ore, pyrite, gypsum, salt, portland cement, petroleum, natural gas, talc, graphite, clay wares and stone. The production of iron ore for 1917 is given as 1,356,011 long tons with a value of \$7,381,333, an increase in value but a decrease in quantity as compared with 1916. In 1918 the production in long tons is 899,970 with a value of \$5,802,870. The production of zinc ore for 1917 totals 47,961 tons and the value based upon the metal contents \$1,059,186. In 1918 the corresponding production amounted to 40,850 tons having a value of \$687,230. Of pyrite

the total quantity for 1917 is 57,075 long tons with a value of \$354,000. In 1918 the amount is 63,982 long tons with a value of \$422,958. Gypsum, the basis of hard wall plasters and plaster of paris, reaches in 1917 the new figure for quantity of 606,268 tons valued at \$2,036,820. In 1918 the production amounted to 531,038 tons with a value of \$2,670,099. Salt, inclusive of rock and evaporated salt sold as such and the salt contents of brine used in alkali manufacture, shows a large gain for the year 1917, with a total yield of 15,457,636 barrels valued at \$5,371,713. Salt in 1918 showed a total of 15,218,071 barrels valued at \$7,336,867. Portland cement is recorded with a production in 1917 of 5,408,726 barrels and a value of \$7,050,656. The same material in 1918 showed a production of 4,074,159 barrels valued at \$6,568,746. The output of petroleum for the year 1917 is practically unchanged from that of the preceding year, amounting to 879,685 barrels valued at \$2,850,378. The 1918 output showed 808,843 barrels valued at \$3,307,814. Natural gas for 1917 shows little fluctuation from 1916, the flow measuring 8,371,747 thousand cubic feet, worth \$2,499,303, and in 1918 a flow of 8,460,583 thousand cubic feet with a value of \$5,673,131, a large increase in value. For talc the output in 1917 of 74,671 tons valued at \$881,462 represents a decline from the 1916 output of nearly 20 per cent. The 1918 output of 71,167 tons shows a small decline but with an increased value, the total production amounting to \$902,100. The product of crystalline graphite in 1917 of 2,941,040 pounds is valued at \$261,548. The 1918 production of 3,266,518 pounds valued at \$273,188 is about the average. For clay-building materials the figures indicate a decided depression, and the outputs for 1917 and 1918 are smaller than for many years. Of building brick the total number for 1917 is only 660,183,000 valued at \$5,118,966, or scarcely 60 per cent of the normal quota. The year 1918 shows a still further depression with a production of but 314,428,000 valued at \$3,063,555. For other clay wares, exclusive of pottery, the aggregate value for 1917 is put at \$2,232,616, which represents about the same proportion of the average product. In 1918 the clay wares showed a total production of \$1,781,927. The production of pottery, however, registers important gains for both years, the combined value of all grades in 1917 being \$4,076,817; the 1918 value \$6,047,472. In the quarry industries conditions during 1917 and 1918 seem to have been active in some branches, but in general the reverse of prosperous. The value in 1917 of the quarry products altogether is placed at \$6,283,556, and in 1918 at \$6,106,756. The large

increase in the output of limestone for the last two years is about balanced by declines in sandstone, trap, granite and marble. Among the miscellaneous materials that enter into the statistics of production for the last two years, with their respective values, are the following: For 1917, natural cement \$41,395; crude clay \$51,505; emery \$170,223; feldspar and quartz \$65,638; garnet \$193,440; millstones \$22,103; metallic paint \$37,282; mineral waters \$562,874; molding sand \$808,550; other kinds of sand, including gravel, \$2,237,897; sand-lime brick \$130,626; slate \$55,207; and apatite, diatomaceous earth, marl, peat, and gasoline from gas wells, of which the aggregate value is estimated at \$100,000. For 1918, natural cement \$7625; crude clay \$41,541; emery \$61,660; feldspar and quartz \$73,230; garnet \$232,661; millstones \$25,488; metallic paint \$10,228; mineral waters \$566,910; molding sand \$770,512; other kinds of sand, including gravel \$1,405,960; sand-lime brick \$79,515; slate \$11,383; and apatite, diatomaceous earth, marl, potash, unclassified stone, gasoline recovered from natural gas, and minerals used for gem purposes \$237,861.

Mineral production of New York in 1916

PRODUCT	UNIT OF MEASUREMENT	QUANTITY	VALUE
Portland cement.....	Barrels.....	5 603 477	\$5 752 809
Natural cement.....	Barrels.....	104 415	51 635
Building brick.....	Thousands.....	982 942	6 497 270
Pottery.....	.....	.....	3 344 672
Other clay products.....	.....	.....	1 913 070
Crude clay.....	Short tons.....	11 158	36 413
Emery.....	Short tons.....	15 282	123 901
Feldspar and quartz.....	Short tons.....	20 379	115 311
Garnet.....	Short tons.....	5 840	198 200
Graphite.....	Pounds.....	a	a
Gypsum.....	Short tons.....	579 827	1 459 587
Iron ore.....	Long tons.....	1 464 917	5 571 429
Millstones.....	.....	.....	10 287
Metallic paint <i>b</i>	Short tons.....	14 572	34 296
Mineral waters.....	Gallons.....	7 746 490	697 650
Natural gas.....	1000 cubic feet..	8 594 187	2 524 115
Petroleum.....	Barrels.....	874 087	2 190 195
Pyrite.....	Long tons.....	a	a
Salt.....	Barrels.....	14 087 750	3 698 798
Molding sand.....	Short tons.....	661 673	570 898
Other sand and gravel.....	Short tons.....	7 436 424	2 073 931
Sand-lime brick.....	Thousands.....	15 851	109 337
Slate.....	Squares.....	2 727	21 345
Granite.....	.....	.....	368 119
Limestone.....	.....	.....	3 672 454
Marble.....	.....	.....	268 391
Sandstone.....	.....	.....	714 558
Trap.....	.....	.....	956 100
Talc.....	Short tons.....	93 236	961 510
Zinc ore.....	Short tons.....	a	a
Other materials <i>c</i>.....	.....	.....	2 011 666
Total value.....	.....	.....	\$45 947 947

a The output is reported under "Other materials" in last item of table.

b Iron ore sold for paint manufacture.

c Includes zinc ore, apatite, diatomaceous earth, graphite, marl, mica and pyrite. The value of the zinc ore is based on that of the metallic zinc recovered from the mine product.

Mineral production in New York in 1917

PRODUCT	UNIT OF MEASUREMENT	QUANTITY	VALUE
Portland cement.....	Barrels.....	5 408 726	\$7 050 656
Natural cement.....	Barrels.....	57 629	41 395
Building brick.....	Thousands.....	660 183	5 118 966
Pottery.....	.....	.....	4 076 817
Other clay products.....	.....	.....	2 232 616
Crude clay.....	Short tons.....	11 894	51 505
Emery.....	Short tons.....	15 941	170 223
Feldspar and quartz.....	Short tons.....	14 271	65 638
Garnet.....	Short tons.....	4 786	193 440
Graphite.....	Pounds.....	2 941 040	261 548
Gypsum.....	Short tons.....	606 268	2 036 820
Iron ore.....	Long tons.....	1 356 011	7 381 333
Millstones.....	.....	.....	22 103
Metallic paint <i>a</i>	Short tons.....	12 557	37 282
Mineral waters.....	Gallons.....	7 819 314	562 874
Natural gas.....	1000 cubic feet..	8 371 747	2 499 303
Petroleum.....	Barrels.....	879 685	2 850 378
Pyrite.....	Long tons.....	57 075	354 000
Salt.....	Barrels.....	15 457 636	5 371 713
Molding sand.....	Short tons.....	650 427	808 550
Other sand and gravel.....	Short tons.....	6 468 586	2 237 897
Sand-lime brick.....	Thousands.....	15 535	130 626
Slate.....	.....	.....	55 207
Granite.....	.....	.....	182 515
Limestone.....	.....	.....	4 406 729
Marble.....	.....	.....	249 180
Sandstone.....	.....	.....	760 582
Trap.....	.....	.....	684 550
Talc.....	Short tons.....	74 671	881 462
Zinc ore <i>b</i>	Short tons.....	47 961	1 059 186
Other materials <i>c</i>.....	.....	.....	100 000
Total value.....	.....	.....	\$51 935 094

a Iron ore sold for paint manufacture.

b Quantity represents crude ore and value represents the estimated value of the zinc contents based upon the average selling prices of spelter in 1917.

c Includes apatite, diatomaceous earth, gasoline, peat and marl; value is partly estimated.

Mineral production of New York in 1918

PRODUCT	UNIT OF MEASUREMENT	QUANTITY	VALUE
Portland cement.....	Barrels.....	4 074 159	\$6 568 746
Natural cement.....	Barrels.....	10 167	7 625
Building brick.....	Thousands.....	314 428	3 063 555
Pottery.....	.....	.....	6 047 472
Other clay products.....	.....	.....	1 781 927
Crude clay.....	Short tons.....	10 120	41 541
Emery.....	Short tons.....	8 183	61 660
Feldspar and quartz.....	Short tons.....	12 998	73 230
Garnet.....	Short tons.....	4 126	232 661
Graphite.....	Pounds.....	3 266 518	273 188
Gypsum.....	Short tons.....	531 038	2 670 099
Iron ore.....	Long tons.....	899 970	5 802 870
Millstones.....	.....	.....	25 488
Metallic paint.....	Short tons.....	3 396	10 228
Mineral waters.....	Gallons.....	5 887 746	566 910
Natural gas.....	1000 cubic feet..	8 460 583	5 673 131
Petroleum.....	Barrels.....	808 843	3 307 814
Pyrite.....	Long tons.....	63 982	422 958
Salt.....	Barrels.....	15 218 071	7 336 867
Molding sand.....	Short tons.....	519 681	770 512
Other sand and gravel.....	Short tons.....	3 653 052	1 405 960
Sand-lime brick.....	Thousands.....	6 776	79 515
Slate.....	Squares.....	853	11 383
Granite.....	.....	.....	191 551
Limestone.....	.....	.....	4 832 348
Marble.....	.....	.....	135 756
Sandstone.....	.....	.....	325 351
Trap.....	.....	.....	621 750
Talc.....	Short tons.....	71 167	902 100
Zinc ore.....	Short tons.....	40 850	687 230
Other materials <i>a</i>.....	.....	.....	237 861
Total value.....	.....	.....	\$54 169 287

a Includes apatite, diatomaceous earth, marl, potash, unclassified stone, gasoline recovered from natural gas, and minerals used for gem purposes.

GENERAL FEATURES OF THE GEOLOGY OF NEW YORK AND THE DISTRIBUTION OF THE MINERAL RESOURCES

Geology supplies the basis for the study of mineral deposits in their broader relations. The first essential in the investigation of the mineral occurrences of a particular region is to become acquainted with the geological conditions — the nature and derivation of the constituent rock materials, their mutual relationships, structural characters, sequence, and the marks of physical and chemical changes that have taken place since their accumulation. Some of this required information may be conveyed by a geological map; an adequate map of the kind serves as a ground plan for the systematic description of the mineral resources of any state or country.¹

New York covers an area of 49,204 square miles, inclusive of its waters which have a surface of 1550 square miles. It has a range of altitude of a little more than 1 mile — from sea level to 5344 feet, the high point of the Adirondacks represented by Mt. Marcy.

Few states of comparable area contain so long a sequence of geological formations and at the same time illustrative of such a variety of characters. Among the formations are representatives of almost every class of the deep-seated igneous rocks and of nearly all the important sedimentary groups from the early Cambrian to the present day. In the Adirondacks the State includes a part of the Laurentian highland, the foundation of the North American continent, made up entirely of Precambrian igneous and metamorphic materials. In the southeastern Highlands, which belong to the Appalachian mountain system, Precambrian strata are also exposed, both igneous and sedimentary, with later sediments lying on the northern flank. The Taconic uplift, with its upturned and metamorphosed Cambrian and Ordovician strata, occupies the area east of the Hudson and north of the Highlands. West of that river and stretching across the State to the western boundaries is the plateau province of Devonian sandstones and shales, giving way on the north to the Lake Ontario plain which is floored mainly by Silurian strata. South of the Highlands, the Hudson Palisades represent an intrusion of basic igneous rock (diabase) in Triassic sandstones and shales. The Atlantic coastal plane of Cretaceous

¹ The inclusion of a geological map with the present report has not been feasible on account of the time required for its preparation, which would have necessitated a long delay in the publication of the volume. Separate maps of the State and in some instances of particular districts may be obtained from the State Geologist on special request. The latest map that covers the whole State is the edition of 1901, on the scale of 5 miles to 1 inch.

and Tertiary strata — the latest addition to the continental area — is represented on Long Island and Staten Island.

The history of the State as traced in its rock formations thus extends from the most remote period of the Precambrian through an ascending series of Paleozoic, Mesozoic and Cenozoic strata to the accumulations of the present day.

Series of the New York Formations in order of occurrence

SYSTEM	STAGE OR FORMATION	ROCK MATERIALS
Quaternary....	Recent.....	Surface, clays, sands, peat, marl
	Pleistocene.....	Glacial till, boulders, unsorted sands
Tertiary.....	Not differentiated....	Bedded clays and sands
Cretaceous....	Not differentiated....	Bedded clays and sands
Triassic.....	Newark.....	Palisades trap, shale and sandstone
Carboniferous..	Sharon.....	Shale and coal "bloom"
	Olean.....	Conglomerate
	Knapp.....	Conglomerate and shale
	Oswayo.....	Shale, sandstone, thin limestone beds
Devonian.....	Cattaraugus.....	Shale, sandstone, conglomerate
	Chemung (Catskill)....	Shale, bluestone
	Portage.....	Shale, bluestone
	Genesee.....	Shale
	Tully.....	Limestone
	Hamilton.....	Shale, bluestone
	Marcellus.....	Shale
	Onondaga.....	Limestone, chert
	Oriskany.....	Sandstone
	Helderberg.....	Limestones (Becraft, New Scotland, Kalkberg and Coeymans beds)
Silurian.....	Manlius.....	Limestone
	Rondout.....	Waterlime
	Cobleskill.....	Limestone
	Salina.....	Shale, gypsum, rock salt, waterlime
	Lockport and Guelph...	Dolomite
	Clinton.....	Shale, sandstone, limestone, iron ore.
	Medina.....	Shale, sandstone
	Oswego.....	Sandstone
Ordovician....	Pulaski.....	Shale, sandstone <i>a</i>
	Frankfort.....	Shale <i>a</i>
	Utica.....	Shale <i>a</i>
	Trenton.....	Limestone, shale, sandstone <i>a</i>
	Black River.....	Limestone
	Lowville.....	Limestone
	Chazy and Pamela.....	Limestone
	Beekmantown.....	Siliceous limestone
Cambrian.....	Potsdam.....	Little Falls dolomite, Hoyt limestone Potsdam sandstone and quartzite
	Acadian.....	Stissing limestone
	Georgian.....	Georgia slates, Poughquag quartzite
Precambrian...	Volcanic.....	Diabase or trap
	Deep-seated igneous...	Anorthosite, granites, syenite, gabbro
	Grenville sediments....	Crystalline limestone, quartzite, graphitic schists, gneiss

a "Hudson River" shales and sandstones.

To indicate the areal occurrence of the mineral resources, the most convenient method will be to divide the State into provinces in accordance with their geological makeup and history. Thus the Adirondacks with their ancient igneous and metamorphic rocks constitute one province, the Highlands with similar formations another, the Taconic area of metamorphosed Paleozoic strata a third, and the interior region of unchanged Silurian and Devonian sediments a fourth. The Palisades with the Newark sandstone and volcanic rocks and the coastal plain of Long Island and Staten Island constitute separate but minor provinces.

Adirondack province. The Adirondack Precambrian province comprises an area of about 12,000 square miles. It is roughly circular in outline with an average diameter of 125 miles. The surface is broken and rugged everywhere, but not uniformly mountainous, although much of it is covered by ridges and peaks that reach elevations of from 1000 to a little over 5000 feet. The ridges usually trend northeast and southwest, parallel with the main folding and fracture lines. Along the borders the Precambrian crystalline rocks are succeeded by Paleozoic strata in horizontal beds, with a profound unconformity to mark the interval between the two series.

The oldest formations are a group of highly metamorphosed sediments, the Grenville strata, which are upturned, often intricately folded and much broken up by invasions of plutonic igneous rocks. The Grenville strata occur in belts and irregular patches that are remnants doubtless of once continuous beds that spread over the whole Adirondacks. Their thickness is not determinable with accuracy although altogether they probably represent a succession of several thousands of feet. Despite their great age the strata do not differ materially from the more recent water-laid detrital deposits — sandstones, silts or shales and limestones — after allowance for the high degree of metamorphism they evidence.

The igneous intrusions that invade and break up the Grenville include enormous bathyliths, like that of the anorthosite in the eastern Adirondacks which is 50 miles across and the syenite bathyliths in the northern Adirondacks, and also as stocks, bosses and dikes. The granites in their molten state seem to have been particularly mobile and fluid, so that their great masses are represented mostly by innumerable dikes, stringers and bosses that have penetrated the Grenville nearly everywhere and effected changes of composition and physical features. The granites also are the most influential of the igneous rocks in contact effects and in places have

converted the limestones into masses of secondary silicates. The last phase of igneous activity is represented by the intrusion of diabase in dikes which penetrate all the other Precambrian rocks and must have occurred late in that era.

The mineral deposits of the Adirondacks are associated with both the igneous and the Grenville sedimentary rocks. Of those having an igneous environment the iron ores are most extensively developed and commercially important. They consist of magnetites in bands, lenses and irregular bodies which have granite and syenite for wall rocks. Another class is the magnetite-ilmenite mixtures in the basic igneous materials—anorthosite and gabbro. The principal deposits of the latter are in the interior of the great batholith, near the Mt Marcy district of Essex county, where there are very large bodies of the ores. The magnetites free of ilmenite are distributed among the smaller batholiths and stocks of the granite-syenite series in the eastern, northern and northwestern Adirondacks, mainly within the limits of Essex, Clinton and St Lawrence counties. The southern and southwestern regions have no considerable deposits. Among other minerals carried by the igneous rocks are apatite which is found in quantity in admixture with the magnetites of Mineville, fluorite also associated with certain of the magnetites, molybdenite in sporadic occurrences in granite of uncertain economic importance, and feldspar, quartz and mica, ingredients of the pegmatitic phases of the granites. All of the materials mentioned are genetically related to the different igneous rocks in whose environment they occur, although there is some doubt about the particular method by which certain deposits have been accumulated. The magnetite-ilmenite mixtures are in the nature of segregations of the gabbro and anorthosite magma, effected doubtless by gravity during the period of crystallization. The same principle may have been operative in the formation of the magnetites of the granite and syenite rocks, although in some examples the influence of mineralizing agencies is indicated by the presence of such minerals as fluorite and apatite while the greater mobility of the magmas has permitted the migration of the ores from their original environment.

The Grenville strata contain a considerable array of ores and mineral materials. Compared with the igneous formations they are more permeable to underground water circulations, having more open spaces and in the case of the limestone especially being considerably more soluble. They are consequently the country rocks for most of the ores assembled as veins and replacements, by the

agency of solvent waters, meteoric or magmatic. Among the important occurrences of ores in the Grenville are the zinc-pyrite deposits of the Edwards district, St Lawrence county, which have limestone for the walls and are in the nature of replacements formed in Precambrian time. The Grenville schists which are associated more or less closely with the limestone carry extensive bodies of pyrite and pyrrhotite with little or no zinc, but allied to the zinc ores in their method of accumulation. In western St Lawrence county occur small veins of galena with subordinate sphalerite which are of Postcambrian age and probably the work of shallow circulations. Hematite in workable bodies is found within the schist and limestone belts of Jefferson and St Lawrence counties. The principal occurrences are in the belt which extends from near Antwerp in the former county through Gouverneur into the towns of De Kalb and Canton, St Lawrence county. They occur commonly near the contact of the two formations, but in places are wholly within the schist. They represent secondary deposits formed after Cambrian time; the source of the iron is likely the pyrite-pyrrhotite bodies already referred to.

Another class of deposits in the Grenville has resulted from metamorphic agencies by which certain components of the rocks themselves have been recrystallized or converted into new mineral varieties, so as to acquire economic value. In this class belongs in part at least the Adirondack garnet that is mined for abrasive purposes. There are a number of localities in Essex and Warren counties where garnet of the almandite variety occurs in large quantities and in some places it is apparently the result of recrystallization of calcareous sediments. The occurrences of the type to be seen in the North River Garnet Company's property, however, seem to be referable rather to the absorption of sedimentary material by igneous rocks. The fibrous talc of the Edwards district, which is mined in large quantity, occurs in Grenville limestone; it is an alteration product of tremolite schist produced by silicification of the magnesian limestone under deep-seated conditions. The valuable graphite deposits of Essex, Warren, Washington, Saratoga and St Lawrence counties are found in quartzite and quartz schist of the Grenville series. The carbon content of the sediments is probably original with them, but the influence of heat and pressure has been required to effect its conversion into the valuable crystalline graphite.

Highlands province. This province includes the igneous and metamorphic terranes of northern Rockland and parts of Orange, Putnam and Westchester counties. The Highlands are a series

of ridges, attaining true mountain proportions in the northern part, that enter the State from New Jersey and continue northeasterly into New England. Their summits are mostly under 2000 feet but they are often very rugged and consequently given up mainly to forest. The ridges die out rapidly on the south side, and in Westchester county the surface is only moderately broken although the crystalline rocks extend over practically the whole area and southward into Manhattan island.

The geology of this region is very complex and much of it still awaits study. Precambrian gneisses are a large element of the crystalline formations; they comprise some igneous types like the Storm King granite-gneiss and also banded gneisses that possibly belong in the Grenville series. With the latter are associated small belts of limestone and quartzite. There are gneisses of syenitic type which resemble the Adirondack syenite, and some of more basic character, but anorthosite apparently is absent. The igneous intrusions continued as late at least as the early part of Paleozoic time; the Cortlandt series of highly differentiated rocks ranging from granite to gabbro and pyroxenite, in the vicinity of Peekskill, is possibly of Silurian age.

The principal ores in this region are magnetites which are associated with the Precambrian gneisses, occurring in belts arranged along northeast-southwest axes, parallel with the general structural trend. A banded gneiss frequently outcrops in the vicinity of the bodies, but this is always injected with granitic material, and granite or pegmatite may usually be found to constitute one wall of the ore. In one or two of the deposits the ore is found on the contact of granite and limestone and has a gangue of secondary silicates. Deposits of magmatic type are represented by the magnetites in the vicinity of Brewster which have a syenitic gneiss for the country rock. Bodies of impure magnetite containing some titanium are present in the Cortlandt gabbros. Corundum is a sporadic ingredient of these ores and its appearance renders the material useful for abrasive purposes, forming a low-grade emery. Arsenopyrite and pyrrhotite are found in one or two localities in the Highlands gneiss belt and have been mined in a small way. Feldspar and quartz are obtained from pegmatites, of which there are many occurrences all through the region, although seldom in workable masses. The largest quarries are in southern Westchester county.

Taconic province. The Highlands on the east of the Hudson river are succeeded northward by a series of ridges which cover the whole area to the Massachusetts and Connecticut state line.

These ridges have a north-south trend, separated by rather narrow parallel valleys. The latter are floored usually by limestone (Wappinger) which has a fine crystalline texture and is usually magnesian. The ridges are made up of fissile schist or hard slate (Hudson). Below the limestone a hard quartzite is exposed in places. The succession consists of Cambrian and Ordovician sediments which have been squeezed into folds and more or less metamorphosed in the process, the limestone and quartzite being now exposed through erosion of the overlying schists along the axes of the folds. The structure is complicated by local faults.

Iron ores and slate constitute the main items in the mineral production of this province. Both limonite and siderite are present, limonite being the commoner ore in most of the developed properties but it is associated not infrequently with siderite and in some places the latter mineral predominates. The deposits lie along the contact of the limestone and schist, more rarely within the schist, and follow the north-south valleys. The ores have been excavated mostly in open pits which seldom attain a depth of over 150 feet. The principal mine localities are in the valley that extends from Hillsdale, Columbia county, south to Dover, Dutchess county, but there are other occurrences in the vicinity of Fishkill and Clove, Dutchess county, and siderite alone occurs in eastern Columbia county, just south of the city of Hudson. Slate is quarried mainly in Washington county in the northern section of the schist belt. The characteristic product is red slate of Cambro-Ordovician age. There are occurrences of purple, green and black slates in that section; some roofing slate has been obtained, also, in Rensselaer, Columbia and Dutchess counties.

Interior Paleozoic province. This covers the part of the State south of the Adirondacks and north of the Highlands to the west of the Hudson river. It is by far the largest province of all, having quite one-half of the total area or around 25,000 square miles. In topography it presents a great diversity, comprising several more or less distinct physiographic units, but in its geological composition and structure it is relatively simple and over great areas uniform.

The formations are all sedimentary, ranging from the Potsdam of the Upper Cambrian to the Olean conglomerate at the base of the coal measures. They lie in approximately the same relative position they occupied when first upraised above the sea, not dislocated by extensive faults nor corrugated by folds, although they have been involved in regional crustal movements and have been deeply dissected by erosion. The formations consist of the usual

array of sediments — shale, sandstones, conglomerates and limestones in varying order — arranged in successive layers or sheets one above the other from the base to the top. Underlying the whole series is the Precambrian basement of granite etc. which has its outcrop in the Adirondacks and the province of Ontario on the north side and the Highlands on the east. The thickness of the sedimentary series increases progressively to the south and southwest in which direction they incline at an average rate of around fifty feet to the mile. From the Adirondacks to the Pennsylvania border the sequence follows in ascending order, beginning with the Cambrian and continuing through the Ordovician, Silurian and Devonian systems as given in the table on a preceding page.

The surface of this province presents greater contrasts of elevation than any other. The lowest parts, along the Mohawk valley and on the Lake Ontario plain, are only 200–300 feet above sea level. To the north of the Mohawk the surface rises rather steeply to the Adirondack foothills, where the sedimentary terrane extends up to altitudes of 500 to 2000 feet; in this part the Paleozoic rocks locally are broken into blocks by faults and have been isolated on the crystalline basement so as to form inliers more or less remote from the main area. The extreme altitudes are reached in the Catskills where the peaks are a little over 4000 feet. The rocks there are not folded or displaced to any wide extent; the mountains are simply the more dissected part of the southern plateau that reaches across the State from the Hudson to Lake Erie. This plateau is composed of a monotonous succession of Devonian sandstones and shales and is bounded northward by the Onondaga escarpment which marks the descent to the Mohawk valley and the Lake Ontario plain floored by Silurian and Ordovician sediments.

The mineral deposits include few of secondary origin. The low-dipping, almost unbroken sedimentary terrane has not been favorable to extensive vein accumulations. Among the ores the Clinton hematite is the only representative of any considerable importance. It is one of the constituent layers of the Clinton formation which otherwise is made up of sandstone, shale and limestone, and is found along the outcrop of the beds from Oneida to Monroe county, disappearing to the south under cover of the higher strata. The layers are thin but cover wide areas and altogether constitute a very large accumulation of the ore. In appearance it differs from any of the other iron ores of the State, having either a fossil or oölitic habit, in accordance with the particular conditions of its deposition which took place at the surface contemporaneously with

the formation of the other Clinton strata. Salt and gypsum exist in extensive bodies within the Salina formation of the Silurian which outcrops across the State from Niagara to Albany county. Gypsum occurs in seams up to 50 feet thick, but mostly from 4 to 8 feet, in the section of the outcrop from Madison county west to Lake Erie. Rock salt is not found at the outcrop owing to its solubility; it is encountered on the dip of the beds at depths below 800 feet or so and within the same east and west range practically as the gypsum. There are often two or three successive layers, separated by shale or limestone with a total thickness of 150 feet or more. Natural gas is present in local pools in the sedimentary series from the Potsdam up to the top of the Devonian. The principal horizons are the Trenton limestone, Medina sandstone, Salina waterlime, Onondaga limestone, Marcellus shale and the Portage and Chemung sandstones. The Medina sandstone is most prolific. The range of the gas pools geographically extends from Lake Erie east to Rome, Oneida county, and from Lake Ontario south to the Pennsylvania line. Petroleum occurs within a very limited area in Cattaraugus, Allegany and Steuben counties, in sandstones of probably Chemung age. The field is a northern extension of the Appalachian field of Ohio, Pennsylvania and West Virginia. In addition to the materials already listed there are occurrences of barium and strontium compounds, small veins of galena, sphalerite and pyrite, and disseminated deposits of pyrite in shales. Clays and building stone are widespread.

Palisades province. The Triassic rocks, which include the trap or diabase that forms the Palisades of the Hudson, are exposed in the southern part of Rockland county. They are more extensively developed across the state line in New Jersey and reappear again in northern Staten island. The Palisades represent the exposed edge of a thick sheet of the volcanic rock that follows in the main the bedding planes of sandstones and shales of Triassic age. The rocks are not folded and there has been no mineralization of importance in consequence of the intrusion, although a little copper is occasionally found in the sandstones. The trap itself constitutes, however, a valuable quarry material; it is exceedingly dense and tough, most useful for crushed stone for concrete and road work.

Coastal plain province. The southern part of Staten island and the whole of Long island fall within the Atlantic coastal plain of Cretaceous and Tertiary sediments. These consist of clays and sands in horizontal beds, still unconsolidated, but concealed in most places by later glacial materials and beach sands. Except for the

morainal accumulations which rise up occasionally into hills 200 or 300 feet high the surface is flat; the moraine covers only the northern half of Long island. The bedded clays in places are serviceable for stoneware and fire resistant materials and the sands for building purposes.

Pleistocene and recent formations. There are practically no sedentary accumulations of clays or sands resulting from the weathering of the subsurface rocks anywhere in the State. Instead the whole area is mantled by a heterogeneous assemblage of boulders, gravels, sands and clays, foreign to the localities in which they occur. It is not uncommon to find great boulders of some of the Adirondack rocks or material from the Canadian highlands at remote distances from their origin. These erratics, as well as the finer materials that are spread over the surface without reference to the underlying formations, were deposited by the Pleistocene ice-sheet which had its sources in the Labrador region of Canada. A collective name for the materials is drift. There is considerable variation in the method of occurrence of the drift. The most general form of deposit is the ground moraine which usually lies directly upon the rocks and consists of a mixture of sand, pebbles and stiff blue clay. It represents mainly the materials melted out of the ice during the retreat of the glacier to the north. It is spread more or less evenly, seldom having a thickness of more than 15 to 20 feet. In places, however, it rises up into ridges 100 feet or more high of characteristic outline, having an elongated oval base and smooth contours that rise more sharply on the north side than on the south. Their longer axis is parallel with the direction of the ice movement which varied from southwest to southeast and locally trended nearly east or west. Drumlins abound in central and western New York. The drift is sometimes in rudely sorted condition as hillocks or kames and long winding ridges or eskers, the result of deposition by the running waters at the end of and under the ice. The obstruction of the earlier drainage by the drift brought into existence many lakes and not infrequently shifted the larger streams into new channels. The surface waters have modified the forms left by the ice to some extent, but broadly the topography is that of a recently glaciated country.

The surface deposits yield quite an assortment of products. The clays are of predominant importance industrially, owing to the extensive local markets for clay-building materials. They are low grade and suitable only for brick and common wares, but have a wide occurrence. The best clays are the water-sorted beds, like

those in the Hudson valley. Sands and gravels for building, engineering and other uses also occur widely. Special grades of molding sand are found in the Hudson valley, glass sand occurs in limited deposits; fire sands, filter sands and other kinds also are represented. Peat is a common material in many of the swamps and shallow lakes, but has not been utilized to any extent. Calcareous marl has the same distribution and is also little developed. Diatomaceous earth abounds in some of the Adirondack lakes as a recent accumulation.

NATURAL LIMITATIONS OF MINING IN NEW YORK STATE

The general characteristics of the mineral endowment of the State have been briefly sketched in the preceding discussion. The important elements of the resources have been pretty well established in the century and more that exploitation has been under way and their distribution defined with more or less certainty by the geological field work that has been in progress for over 80 years. It seems a reasonable deduction that future mining developments will be based largely upon the possessions whose description forms the basis of the present report.

The writer does not intend to imply that there are no resources of ores and minerals still awaiting discovery nor that new uses may not be found that will create demands for materials which have little value at present. There is every reason to forecast the growth of the mineral industry in both ways on the basis of what has taken place within the last few years. The recent establishment of a prosperous zinc mining industry in a district where mining of other minerals had been going on for a long time is an illustration of the possibilities for new developments to be found in the State. But the main advances in the future are to be looked for in the intensive exploitation of the mineral supplies already known to exist and in line with past operations. It may be confidently expected that opportunity for new enterprises will be provided by further improvements in the methods of production and preparation of minerals, through the extension of transportation facilities into some of the remoter districts now scarcely open to development, and by the normal increase of market demands, which will bring additional deposits within the field of practical operation.

There are some important branches of mining for which no substantial basis may be found within the State. One of the most essential commodities in modern industry — coal — is not represented in the list of products and is not likely ever to be mined here, although the northern limits of the Appalachian coal field approach so closely to the southern bounds of the State that some reason may have existed in earlier years for the search after deposits. A shifting of the boundary line by a few minutes of latitude would bring a part of the Pennsylvania coal fields within the State limits. However, the stratigraphic position of the measures and the futility of looking for coal anywhere in New York were demonstrated by

the work of the First Geological Survey, and it is an inexcusable waste of effort to continue the search. Yet ventures of this sort are being promoted almost constantly and in some instances that have come to the writer's notice they have entailed a very considerable financial loss. In the Catskills and southern tier of counties the stratified formations most closely approximate in age the period of deposition of the Appalachian coal, but they belong mostly to the uppermost Devonian horizons and thus antedate the first coal measures which occur in the Carboniferous. There are small isolated areas of Carboniferous strata in Cattaraugus and Allegany counties, mainly represented by conglomerates, which indicate a possible occurrence of the overlying coal measures in past geological ages, since swept off by erosion.

The precious metals also are not present in New York in workable quantity. The efforts to promote enterprises for exploiting deposits of these metals should be deprecated as sure to entail loss upon the financial participants and as working an injury upon legitimate enterprises. The writer is well aware of the fact that it is not possible to substantiate the statement as to the absence of gold deposits with the same positive evidence that exists in reference to coal, but the collateral evidence and inferences have sufficed to demonstrate its truth with respect to all of the deposits that have thus far been reported to carry the metal.

A great deal of attention has been given in the last 25 years to the so-called gold sands of the Adirondacks. These have been widely advertised as yielding anywhere from \$4 or \$5 to \$50 a ton when subjected to treatment by special processes. Many plants have been erected in different parts of the region based on methods that seem to be the principal consideration of value in the promotion schemes, since the deposits for which they are intended are in no way different from the ordinary glacial and alluvial sands that cover a great part of the Adirondacks. Repeated tests of the sands by the usual procedure of assayers have failed to indicate more than a trace of gold—a few cents a ton at most—such a quantity as may be found in almost any rock material. The discrepancy between the claims of the process promoters and the results of ordinary assay is said to be explainable by the peculiar condition in which the gold exists. The terms “nascent,” “atomic” and “volatile” are frequently applied in the prospectuses to convey this idea. A little knowledge of chemical principles suffices to demonstrate the fantastic character of the information published in the interest of these ventures.

The possibility of gold occurring in the Adirondack sands to any appreciable extent is excluded by the lack of any primary accumulations of the metals in lodes or veins. There are no quartz veins anywhere which carry gold in quantity. Common vitreous or milky quartz to be sure is not uncommon but it lacks the sulphides that are the almost universal accompaniments of gold in its primary distribution. The Adirondack sands are simply the products of weathering and erosion of the common country rocks of the region; they contain more or less magnetite, mica, garnet and feldspar in addition to the quartz which constitutes the main ingredient, but repeated assays have failed to detect more than mere traces of gold.

The occurrence of silver in some of the galena found in the Adirondacks and southeastern New York is a matter of authentic record. Aside from such small quantities, of no commercial interest in themselves, the conditions in regard to silver are the same as those for gold.

Platinum is one of the rarest of metals and its value in the chemical and electrical industries has stimulated a lively search for deposits. In its physical properties it somewhat resembles gold, and readily concentrates in placers where there are original sources of supply for them to form. Its presence may be easily ascertained by chemical assay. The only occurrence of the metal in New York State that has any substantial basis in fact is the reported discovery of a mass of mixed chromite and platinum weighing 104 grams (of which platinum constituted 46 per cent) in the vicinity of Plattsburg. The record of the occurrence seems to be authentic. If the specimen was found in place and had not been brought there by human agency, it probably came originally from some of the serpentine areas of northern Vermont or southern Quebec and was brought down by the ice. There are no chromite deposits in the Adirondacks, although the mineral is found in small amounts in the Highlands region. No further basis than this exists for the recent claims that the Adirondacks carry platinum.

APATITE

The common carrier of phosphorus in rocks and ores is the mineral apatite which is essentially calcium phosphate, although it contains also small amounts of the fluoride and chloride of calcium. Apatite is the source of phosphorus in iron ores, its proportions determining largely the quality of the iron that may be made from particular ores; and is widespread in many rocks, especially of the igneous class, but rarely constitutes more than one per cent of the mass. Though a very common mineral, there are few deposits of apatite which would repay the costs of mining for itself alone. The abundant rock phosphates, which resemble apatite somewhat in composition, serve most requirements quite as well and are obtainable at a low cost.

Apatite and phosphate materials generally are sold on the basis of chemical analysis. Rock phosphate ordinarily carries from 60 to 70 per cent of the tri-calcium phosphate or bone phosphate, whereas apatite in pure state contains 90 per cent. If an apatite concentrate were obtainable with an average of 75 or 80 per cent of bone phosphate it would have a certain preference in the market by reason of the scarcity of materials of that grade which are serviceable for the manufacture of metallic phosphorus and chemical preparations.

The production of apatite is carried on at present in one locality as a by-product of the mining and milling of iron ores. This is Mineville, Essex county, where Witherbee, Sherman & Co. have for years been engaged in the production of an apatitic magnetite that occurs in the so-called Old Bed group of deposits. The ore as mined carries as much as 8 or 10 per cent of the phosphate mineral in the form of small grains or crystals intermixed with the particles of magnetite. By crushing the apatite is mostly released from mechanical combination and can then be separated readily by the usual magnetic methods employed for concentrating lean magnetites. Although the magnetite in this instance is sufficiently high in iron content to be used in lump form, its treatment is desirable for most furnace uses. As a result of the separating process a tailing is made which contains most of the apatite originally present in the ore, a small percentage of magnetite and considerable amount of quartz, hornblende and feldspar which are constituents of the gneissic country rock. Large quantities of these tailings have resulted from milling of the Old Bed ores. In order to put them in form for commercial use they require further treatment. They are reground and reconcentrated in magnetic machines, wet tables

and jigs until the phosphorus content is raised to at least 8-9 per cent, corresponding to 40-45 per cent of bone phosphate. As illustrative of the effect of the process the following analyses are of interest, although not strictly representative of present day conditions. No. 1 refers to the crude ore, no. 2 to second grade apatite concentrates and no. 3 to first grade apatite concentrates.

	1	2	3
Iron.....	59.59	12.14	3.55
Phosphorus.....	1.74	8.06	12.71
Bone phosphate equivalent.....	.....	40.30	63.55

The concentration at present is carried only so far that the phosphate content reaches 40 to 45 per cent. The product is finely ground and admixed with barium sulphide, constituting an agricultural fertilizer which is sold as "barium-phosphate." In its properties the material is analogous to basic slag which has been extensively employed for fertilizer in Europe, and it combines the fertilizing value of phosphorus with an alkaline reaction that promotes nitrification.

There are no other deposits of magnetite in the State, so far as known, that contain enough apatite to justify similar operations for its recovery and utilization.

The occurrence of apatite in the crystalline limestones of the State may be noted, but rather on account of their mineralogical interest than of possible commercial importance. Among the localities which afford good crystallized specimens are Gouverneur and Hammond, St Lawrence county; Natural Bridge, Lewis county; and Amity, Orange county. The contact zones between intrusive granites and limestones are frequently characterized by the presence of apatite.

A phosphate mineral called eupyrochroite, an amorphous calcium phosphate closely resembling apatite, has been produced on a small scale in years past. The single known occurrence is just south of Crown Point, Essex county, near the shore of Lake Champlain. It is mentioned in the reports of the First Geological Survey, and mining operations were carried on for a time about the year 1850 with the production of 100 tons or so of the material for use as fertilizer. The usual form of the substance is a massive aggregate, sometimes showing concretionary or botryoidal structure, of bluish to grayish color. When heated it gives a phosphorescent green light. An analysis by Charles T. Jackson published in the *American Journal of Science*¹ showed 92.94 per cent of tri-calcium phosphate.

¹ Series 2, v. 12, 1851.

ARSENICAL ORE

The arsenical minerals used for the preparation of arsenical compounds include arsenopyrite (iron sulpharsenide), and leucopyrite (iron diarsenide). Both occur in New York State. In addition the hydrous arsenate of iron, scorodite, and the arsenical sulphide orpiment, are known to occur, but are without economic interest.

An occurrence of arsenopyrite in the Highlands near Pine pond, town of Kent, Putnam county, represents the most important deposit that has actually been developed and exploited for arsenical ore. It was worked in the years 1906-1907 by the Putnam County Mining Corporation which installed a mining and milling plant on the property and shipped a considerable quantity of concentrates as well as several hundred tons of lump ore which was sufficiently high in arsenic to be merchantable. Some of the output went abroad. The deposit was under operation also for a brief time about 1888; a small quantity of ore is reported to have been shipped at that time to New Jersey for treatment. The first exploration seems to date back to 1847. A description of the deposit was given in the issue of the Mining and Quarry Industry for 1906.

So far as revealed by existing developments, the deposit appears to be a vein intersecting gneiss which is the prevailing formation in this section and includes both igneous and sedimentary varieties. The vein lies near the base of a prominent ridge, southwest of Pine pond. It has a northerly strike. In close proximity and running parallel is a dike of basic rock, the outcropping portion of which is completely altered to serpentine. The dike rises above the surface as a distinct ridge that can be traced for half a mile or more along the strike and shows a width of from 100 to 300 yards. It is probably a peridotite, though the nature of the original silicate minerals can only be inferred from the general appearance and texture, as they are completely altered to serpentine.

The vein consists of white flinty quartz with varying proportions of arsenopyrite and pyrite. In places the metallic minerals occur in solid mass, but usually they are distributed through the quartz. Pyrite is much the less abundant of the two, its distribution being very irregular. Both are seldom crystallized. The percentage of metallic arsenic in the ore ranges nearly up to the theoretical amount required by the chemical formula. With hand sorting a fairly large proportion will assay above 25 per cent which is considered marketable.

A mixed sample of the high and low grade ores was analyzed by H. F. Gardner of the Museum staff with the following results:

SiO ₂	26.84
Al ₂ O ₃	.26
Ca	.01
Mg	Nil
P ₂ O ₅	.05
S	25.07
Fe	28.83
As	18.51
Cu	.16
Mn	tr
Co	Nil
Ni	Nil
	99.73

The figures indicate a mineral composition of 40.20 per cent arsenopyrite, 32.31 per cent pyrite and .39 per cent chalcopyrite.

An analysis of the dike, which has also been reported by the Company, is sufficiently interesting to deserve record. It establishes the ultra-basic nature of the rock and is in agreement with the view above expressed that it is an altered peridotite.

SiO ₂	35.50
Al ₂ O ₃	4.52
Fe ₂ O ₃	7.40
CaO	2.60
MgO	37.64
CO ₂ }	13.30
H ₂ O }	
	100.96

Leucopyrite, arsenopyrite and scorodite are reported¹ to occur at Edenville, Orange county. According to Whitlock² arsenopyrite is found here in association with gypsum and orpiment, embedded in white limestone; while leucopyrite is distributed through a dioritic rock. A prospect in which considerable work has been done is located on the Brown farm between Edenville and Mt Adam. Arsenopyrite is also listed in the report by Beck already cited as occurring in the town of Lewis, Essex county, 10 miles south of Keeseville.

Most of the arsenic of commerce is now obtained as a by-product of smelting operations in which the arsenious oxide (white arsenic) is recovered from the smelter fumes, at relatively small cost. Consequently the ores of arsenic are of less interest than formerly.

¹ Beck. Mineralogy of New York (1842).

² Whitlock. N. Y. State Mus. 23d Rep't of State Geologist, 1903.

ASBESTOS

The minerals which supply the asbestos of commerce are known to occur in several places within the State, more especially in the crystalline areas of the Adirondacks and southeastern New York. They are nowhere mined at present, but the occurrences have been at different times the object of inquiry and more or less attention which in one instance has extended to considerable exploratory work. The purpose of this article is to mention the different localities which have come to light and to give whatever information is available concerning their features and possible importance.

That the local occurrences have aroused some interest from a commercial standpoint is not surprising in view of the recent great development in the uses of asbestos and of the remarkable growth of the Canadian mining industry which supplies the larger share of the world's needs of the material. The principal mines of Canada are situated in the province of Quebec, on the south side of the St Lawrence river, not very remote from the northern boundary of New York. The district in fact extends southward across the Vermont line, in which State there are similar occurrences which have more or less importance.

The proximity of the Adirondack crystalline region to that district might be regarded as favorable to its carrying the same kind of deposits, but there is really no basis for such inference as a little consideration will show. The asbestos of Canada and Vermont is found within a belt of metamorphosed Paleozoic formations which lie along the flanks of the Green Mountain uplift. The particular home of the mineral is in serpentine, in this case the product of alteration of old igneous rocks originally composed of minerals of the olivine and pyroxene groups. A large number of serpentine bodies are known in the stretch from southern Vermont into and across the eastern townships of Quebec, but in only a few is asbestos present in workable proportions. The mines or quarries are based on masses of serpentine that carry closely crowded veinlets of chrysotile, the latter occurring in such profusion as to permit the excavation of the whole mass, from which the fiber is then obtained by hand picking or by milling operations.

No similar bodies of serpentine are found in the Adirondacks. The latest igneous intrusions in that region took place before the opening of the Cambrian period, and the sedimentary formations were laid down at a much earlier date. The igneous intrusions did not include any rocks of the peridotite class (composed of olivine) and consequently there has been no material from which large serpentine

masses could develop. The occurrence of serpentine and of chrysotile is limited to the crystalline limestones which are found in belts and in which the serpentine is disseminated in nodules, bands and small particles in the midst of the carbonate minerals. The proportion of serpentine to the whole rock is variable; in some places it may constitute the greater part but usually it plays a subordinate role, being one of several impurities of the limestones. It is a secondary product, formed in most cases by the alteration of a pyroxene mineral. The asbestos is a variety of the serpentine that occurs in small veins, rounded aggregates and irregular patches. It is apt to be very irregular in its occurrence, but is sometimes rather abundant within limited areas of the limestones. The fiber looks like the commercial fiber of Canada and Vermont but seems to be of lighter color and greater transparency. From the features of its development it is regarded as a vein mineral, deposited in cracks and cavities, by solutions circulating through the limestones and probably derived from the disseminated serpentine which, as stated, is an alteration of pyroxene.

Serpentinous limestones are not at all rare in the Adirondacks; in fact they are rather common in the eastern part in Essex and Warren counties and also in the northwest in St Lawrence county. They are associated with the normal crystalline limestones, of which they are only a special development, the serpentine itself having no geological significance. In some places the rock has been quarried as an ornamental stone, since the greenish serpentine particles with the white or bluish dolomite base give a very pleasing effect that makes the stone suitable for interior decorative work. Some of the better known localities for these serpentinous marbles are just north of Port Henry on Lake Champlain, in western Moriah township, near Minerva and Olmstedville, all in Essex county, and in the town of Thurman, Warren county.

Wherever the serpentinous limestones are found asbestos may be expected in greater or lesser amount, though of course as a subordinate constituent.

The principal occurrence of this nature that has thus far been uncovered is in the town of Thurman, about 7 miles west of Thurman station on the Adirondack branch of the Delaware & Hudson Railroad. There is a large area of crystalline limestone which here and there contains bands charged with serpentine occurring as rounded and irregular patches of some size but irregularly distributed and as small grains that are more evenly scattered through the mass. Such a band was prospected a few years ago, resulting in the produc-

tion of a small quantity of chrysotile or serpentine asbestos. The latter occurs principally within a small but rather persistent zone of the limestone that takes a northeasterly course parallel to the general structural trend. Within this zone occur numerous veinlets that carry a very light, silky asbestos of a maximum length of about an inch, most of which is apparently of good quality. The veins are not persistent, but thin quickly and merge into the massive serpentine of the country rock. Outside the main zone, bunches of serpentine are to be seen which are shot through with fiber, or show the presence of whitish asbestiform material. The general average of the fiber is probably not more than one-fourth of an inch. Samples were shipped by the owner of the property to asbestos manufacturers who reported favorably upon its quality. Although a part of the rock, no doubt, is of workable grade, not a very large quantity of that kind has as yet been exposed in the workings.

A small prospect showing serpentine asbestos of fairly long fiber was seen by the writer some years ago on the north side of Brant lake, in the town of Horicon, Warren county. It is not known by whom the property was explored, but apparently the results did not warrant a continuance of the work.

Serpentinous limestones are also found in the Highlands region in Putnam and Orange counties; from the locality in Philipstown east of Cold Spring many samples of chrysotile have been gathered for museums. Mather in the New York Geological Reports for 1839 mentions an occurrence at Cotton rock in the same town on the bank of the Hudson, $3\frac{1}{2}$ miles below West Point.

On Staten Island and near the Village of Rye, Westchester county, are bosses of serpentine which furnish the closest parallels to the Canadian and Vermont occurrences. The Staten island boss has a surface of about 15 square miles and constitutes the central elevated part of the island. The rock is apparently an igneous derivative, as unaltered remnants of olivine and pyroxene have been discovered in it. Both amphibole and serpentine asbestos occur within the area, the former variety being restricted to the border where the serpentine is in contact with schistose rocks belonging to the Manhattan formation. Examples of amphibole asbestos have been collected from Pavilion hill near Tompkinsville and at Fort George; one specimen found by the writer near the latter place possessed fibers nearly a foot long. Chrysotile is less common, but a very few years ago was still to be found on Pavilion hill.

BARYTES

The common barium mineral in this State, as usually elsewhere, is the sulphate (BaSO_4). It is a heavy substance, noticeably heavier than the usual run of non-metallic minerals, and is quite resistant to ordinary solvent agencies. It occurs in masses of white color and often in crystals, clear and transparent or tinted by some impurity. It is not infrequently so stained with iron as to conceal its real color. Barytes or barite belongs to the group of minerals that occurs mainly in veins; it sometimes occupies the vein by itself, or may form the gangue for metallic ores, especially those of lead and zinc. The wall rock is usually limestone.

Uses. The industrial uses of barytes are varied. It is largely sold in ground form and in that condition is employed directly for admixture with lead pigments and metallic paints, for filling paper, in rubber manufacture and as an adulterant of many commodities in which it serves to give body and weight but is inert. It is the base from which the barium sulphide is prepared for making lithophone. This is a mixture of barium and zinc compounds, used for pigment, enamels and filling of cloth and paper. There are several compounds of barium important in the chemical industry and chemical laboratory that are made from barytes. In addition to grinding, the preliminary treatment of crude barytes may involve "bleaching" to remove iron stain; this is performed by subjecting the ground product to the action of sulphuric acid which removes the iron in solution. The white powder is then washed with water.

Occurrence. Barytes is found in many localities, but in general the deposits are too small to be worked. One of the few occurrences that have been mined is on Pillar Point, Jefferson county, a small peninsular area of Trenton limestone that juts into Lake Ontario just north of Sacketts Harbor. The barytes is found filling small veins on the north shore of the point and is practically free of admixture. Masses 2 or 3 feet long and a foot or more thick were taken out in the period of mine operations which were carried on about 1840. The material, as exemplified in specimens in the State Museum, consists of a massive banded variety and of crystals somewhat iron-stained but of good quality. There are no records to indicate the quantity removed from the veins, but it could not have been very large, judging from the conditions revealed at the present time. A brief account of the occurrence contemporary with the mining period is given by Lewis C. Beck in the reports of the First Geological Survey.

Among the other localities for barytes in northern New York are Richville, Hammond, Gouverneur, De Kalb, Rossie, Fowler and Edwards, St Lawrence county. In the old lead mines of the town of Rossie it occurs associated with calcite as gangue. In Fowler it is found in geodes associated with hematite. The gangue of the Edwards zinc ores contains 1 or 2 per cent of barytes in fine lamellar crystals which are plainly evidenced in the process of separation of the zinc sulphide. Crusts made up largely of this mineral were collected by the writer from the weathered outcrop of the zinc deposits.

In the impure dolomitic limestone near Little Falls barytes occurs in crystals within small veins and geodes and is frequently characterized by the occlusion of hydrogen disulphide. It is reported also from Fairfield, Herkimer county. At the Ancram lead mines in Columbia county it forms small veins that traverse the slate and limestone wall rocks.

In Schoharie county, town of Schoharie, barium is present in the celestite which occurs in considerable quantity as nodular aggregates of delicate crystals within the Brayman shales and in the Rondout waterlime. It may also be present as barytes in mechanical mixture with celestite and strontianite. The occurrences have been described by Prof. C. U. Shepard¹ who applied the name "calstronbaryte" to one form of material which apparently is a mechanical mixture of barytes, calcite and strontianite. Beck supplies a record of the occurrence of barytes in Schoharie. "Heavy spar also occurs associated with strontianite, in the water limestone in the vicinity of Schoharie courthouse. In such cases it is generally found in the form of laminae which cleave readily, and sometimes present two or more faces of the primary prism. In all the specimens which I have examined, it is mixed with carbonate of lime, and also with portions of strontianite. Indeed, these two substances are so abundant in this limestone that the massive specimens of heavy spar are seldom pure."

Beck in his report also mentions a locality in the town of Carlisle, about 8 miles northwest of Schoharie village, where a fibrous form is found in considerable abundance in a dark shale. The latter may be the Brayman shale.

Grabau² has described a strontium-barium sulphate from near Schoharie where it occurs in the waterlime that is exposed on the

¹ American Jour. Sci., v. 27, 1835.

² Geology and Paleontology of the Schoharie Valley, N. Y. State Mus. Bul. 92, p. 360-61, 1906.

cliff east of the village. "Loose specimens are found in the stone fences and may be recognized by their color, crystal form and great weight. The mineral was examined chemically by Dr V. J. Chambers of Columbia University who found it to be strontium sulphate, with some barium sulphate admixed. From this analysis it appears that the mineral is in reality barytocelestite."

References

- Beck, Lewis C. Mineralogy of New York. 1842
Gebhard, John. On the Geology and Mineralogy of Schoharie, N. Y. Amer. Jour. Sci., v. 28, 172, 1835
Grabau, A. W. Geology and Palontology of the Schoharie Valley. N. Y. State Mus. Bul. 92, 1906
Shepard, C. U. Amer. Jour. Sci., v. 27, 1835
Whitlock, H. P. Minerals not Commercially Important. N. Y. State Mus., 57th Ann. Rep't, 1904

CARBON DIOXIDE

Carbon dioxide is classed as a mineral when it occurs free, naturally stored within the earth. Mostly it is produced artificially by combustion of coal or coke, by fermentation in brewing and by calcination of mineral carbonates like limestone, dolomite and magnesite. Its principal use is in the carbonating of beverages.

Natural carbon dioxide exists in the mineral waters of Saratoga and Ballston springs, being held in solution by the waters as they occur in the underground reservoirs and separating from them as they issue at the surface with diminishing pressure. For many years its collection and distribution was an industry of importance in Saratoga and vicinity, the value of the output exceeding that reported for the sales of mineral waters by themselves. The industry was finally discontinued with the erection of the State reservation and the cessation of pumping under legal restraint. Since then no gas has been sold separately, although the natural supplies are used locally in the charging of the bottled mineral waters for general consumption.

The presence of large quantities of free carbon dioxide in the waters is the most interesting and intrinsically important feature of the Saratoga-Ballston district. There is no other spring resort in the State or in the whole eastern part of the country that is comparable in that respect. Similar examples of highly carbonate waters are found on the Pacific coast and at some of the celebrated European spas. The sources of the gas is an unsolved problem, further than that it must come from great depths before it joins

the body of artesian waters which have their head at some distance from the Saratoga fault where they are collected. Professor Kemp¹ who has made a special study of the springs is inclined to the opinion that the gas is essentially an igneous emanation, produced through the cooling of a magma at depth. The gas might be occluded in the molten material, as seems to be the condition in the gaseous emissions from active volcanoes, or on the other hand might be set free from limestones by heat or a chemical reaction induced by the deep-seated igneous magma. Another explanation which has been frequently advanced by other students of the problem is that the gas is produced in the superficial zone by the action of a free acid, like sulphuric acid, upon the Paleozoic limestones which directly underlie the surface. The acid, it is thought, may be derived by oxidation of pyrite in the accompanying shales. As against this interpretation there is no evidence of a sufficient supply of free acid to cause the decomposition of limestone on a scale demanded by the quantities of carbon dioxide present, or of the resultant calcium sulphate of which quantities would be left behind as gypsum, since the amount of dissolved sulphates in the waters is small. No doubt the solvent properties of the carbon dioxide is responsible for much of the saline matter carried by the waters.

The relative amount of carbon dioxide in the Saratoga waters varies considerably in the individual wells. As many as five or six volumes are reported to have been present in some of the best wells drilled by the gas companies whose properties were situated to the south of the village and at Geysers. The general average may be taken at two or three volumes. At atmospheric pressure water is able to retain one volume of the gas, but its solvent power greatly increases with pressure, which accounts for the presence of so large quantities in some of the naturally stored waters that are under hydrostatic load. As the water comes to the surface and pressure is released the gas is evolved and causes the lively boiling noticed in the Saratoga waters as they issue from the wells.

In the most active period of the carbonic gas industry, in the four years immediately preceding 1908, when the further production was enjoined by law, there were five gas collecting plants that employed about thirty wells altogether for the purpose. The product ranged from 4,000,000 to 5,000,000 pounds a year. Pumps were used to bring the water to the surface where the gas was separated and conducted through a pipe to the gas holders for storage previous to liquifying and charging into cylinders.

¹ The Mineral Springs of Saratoga. N. Y. State Mus. Bul. 159, 1912.

CEMENT

Raw materials for cement manufacture are abundant and widely distributed. They support an active industry which, so far as production is concerned, finds its limitations mainly in the commercial relations that govern the distribution and sale of the product in competition with the output of adjoining States. New York is one of the largest markets for hydraulic cement in the country and its consumption in recent years, abnormally increased by the extensive public improvements that have been carried out, has far outstripped the local production capacity; there is keen competition however, at all important centers with the product of mills in adjoining areas and notably those of eastern Pennsylvania. Notwithstanding the extensive demand, therefore, the prices obtained for cement over a period of several years have not been favorable enough to encourage many new additions to the list of cement plants.

Both natural and portland cements are made. The former industry was first established in the State and during a period of 75 years or more it commanded a large and profitable trade. The vicinity of Kingston was the principal center of natural cement manufacture; the product of that region was marketed under the trade name of Rosendale cement, recognized as the standard for this grade all over the country. At the height of the industry the output of natural cement in New York exceeded 4,000,000 barrels a year. Portland cement began to appear in the market as a strong rival of natural cement in the closing years of the 19th century, although it had been made here for some time and had been imported from England for a still longer period. Improvements in the process of manufacture had been worked out and put in practice at about that time which so cheapened the costs that portland cement could be sold nearly on a parity with the natural brand, while it also gained favor through its superior properties, especially in regard to uniformity. From about the year 1900 the natural cement business began to decline, and in the last few years the output has dwindled to small proportions.

PORTLAND CEMENT

Resources of materials. The raw materials for portland cement manufacture include limestone, clay or shale, and gypsum. Coal for fuel is an essential of course whose cost must be taken into account in the economics of plant locations, but the main con-

sideration is to find a suitable combination of limestone and clay. Marl may take the place of hard limestone, but is not so desirable from a manufacturing standpoint on account of the large amount of moisture present. Shale of suitable composition is as good as soft clay. Gypsum performs a subsidiary function in the cement mix, acting simply as a retarder for the high-lime, quick-setting cements, and is added in such small proportions that the existence of a nearby supply is not of great moment. All of the elements necessary for making portland cement, with the exception of coal, are provided by the local resources. The soft coal fields of Pennsylvania are within easy shipping distance of most parts of New York State.

Clay, as noted in the special part of this report devoted to that subject, covers wide areas, and is further supplemented by extensive shale deposits which occur in the series of stratified formations. There is practically no considerable section in which argillaceous materials suitable for cement mixture are not present. High-calcium limestones on the other hand have a more limited development, so that their distribution and consideration of their local availability may be regarded as of fundamental importance in the location of plants.

It is to be noted that the term high-calcium is not used strictly in a quantitative sense. Limestones may contain considerable percentages of impurities in the form of silica, alumina, iron and alkalies and still be very serviceable for cement. Silica and alumina are desirable in that they take the place of so much clay, and iron is allowable, if not present as sulphide. It is well to remark, however, that in the case of impure limestones there should be a degree of uniformity in the composition that will admit of the easy attainment of the proper mix. A marked variation in this respect will necessitate very careful oversight, if not excessive labor, to maintain the proper proportions between the different ingredients.

Many limestones contain magnesia as a substitute for the lime, in which case they are called magnesian limestones if the percentage is low, or dolomites if the magnesia attains proportions of 15 per cent or so. The proportion of magnesia is determinable with certainty only by analysis. For portland cement it is important to ascertain the amount of magnesia in the average rock, as the presence of more than 4 per cent in the finished product will exclude the use of the cement under standard American specifications.

In view of these limitations as to quality, the selection of a limestone supply must be made with some care, giving due regard

to the possible variations that may take place in the several beds to be worked. Obviously no general classification of the different limestone formations can be made upon the basis of composition. However, certain formations are more likely to contain suitable material than others. Broadly speaking, the chief supplies of high-calcium limestones are to be found in the following geologic groups or formations: Grenville, Chazy, Trenton and Black River, Clinton, Helderberg, Onondaga and Tully. Their stratigraphic range is thus from the early Precambrian to the middle of the Devonian. To these groups might be added the marls found at the surface and of recent (Quaternary) age, but as already noted the use of marls seems to be no longer economically practicable.

The distribution of limestones in the State is discussed briefly in the section "Stone" elsewhere in this volume and has been described at length in New York State Museum Bulletin 44, "Lime and Cement Industries of New York."

The fact that the Grenville formation contains limestones that fulfill the chemical requirements of portland cement manufacture seems to have escaped attention in most of the published accounts of the local supplies. The Grenville is, however, notable for the extensive development of carbonate rocks which range from those high in lime to magnesian limestones and dolomites. They all have a crystalline texture in contrast with the limestones of the later or Paleozoic formations. They have long been successfully employed for lime burning and are probably equally adaptable to cement manufacture. Their occurrence is restricted to the Adirondacks and southeastern Highlands, the larger areas being on the north-western side of the Adirondack region in St Lawrence county. As a rule they are low in silica and alumina, but rather high in magnesia which locally may fall within the admissible proportions.

Industrial development. The earliest commercial operations in portland cement manufacture in New York were inaugurated in 1881 by the Walkill Portland Cement Co. with works at Carthage Landing, near Beacon, on the Hudson. The supply of limestone was obtained from the vicinity of Kingston and the burning was performed in upright kilns with coke from the municipal gas plants of New York and Albany. The product found a ready sale and the enterprise was so successful that a second plant at South Rondout near Kingston was erected and placed in operation in 1883. The latter had a capacity of 200 to 300 barrels a day. Fire destroyed this plant in 1889, after successful experiments had been made with a rotary kiln using oil for fuel, the first venture of the

kind in America. The cement mix was charged into the kiln without briquetting. In 1886 a cement works was put in operation by T. Millen & Sons at Warners, Onondaga county. The materials employed were local Quaternary marls and clays. The plant was purchased by the Empire Portland Cement Co. in 1890 who operated it for some 15 years, in the meanwhile changing the equipment from stationary to rotary kilns and extending the capacity. Another plant designed for the use of marl and clay was erected at Montezuma, Cayuga county, in 1890; the installation included a 75 foot rotary kiln in which the cement mix was charged wet and burned with oil injected in vaporized form. This foreshadowed by many years the general practice of burning the raw materials without mechanical preparation in long rotary kilns. The principal changes in subsequent practice have been to substitute pulverized coal for oil and to increase the length and diameter of the kilns. The Montezuma plant was destroyed by fire in 1893.

The active period of portland cement manufacture may be said to date from about 1890, from which time the production began to assume considerable proportions. In the earlier years the output averaged less than 50,000 barrels. In 1890 it amounted to 65,000 barrels and thereafter showed a steady gain so that by 1898 it reached 554,358 barrels and in 1902 exceeded a million barrels.

The industry did not become really stabilized, however, until about 1905. Many enterprises had been started under the favoring conditions of high prices without much reference to the basic conditions of market facilities, and these were destined to succumb to competition with the plants that had better access to the main centers of consumption. Also, the employment of marl in the place of hard limestone proved to be an economic, though perhaps not a technical, mistake. Marl plants were erected at other places in addition to those already noted, namely by the American Cement Co., at Jordan, Onondaga county; by the Wayland Portland Cement Co., Wayland, Steuben county; and the Iroquois Portland Cement Co., Caledonia, Livingston county. By 1910 all of the marl plants had either been converted for the use of limestone or had gone out of business.

At present the manufacture of portland cement is on a firmer basis, with a better outlook for the future, than at any time in the recent history of the industry. There have been few new enterprises started in the last several years, but practically all of the mills have been improved, remodelled or enlarged to meet the requirements of the best practice. In consequence the local industry has been able

to strengthen its position and increase its production at a time of unrestricted and intense competition.

The larger part of the manufacturing capacity of the State plants is represented by the mills along the Hudson river below Albany. This district includes a narrow strip on the river in Greene and Columbia counties where limestones of the Cayugan and Helderbergian formations have been exposed in ledges by the cutting down of the valley across the general strike. This district possesses great advantages for the shipment of cement, since it has easy access to tidewater and important markets on the adjacent seaboard. There are five mills in the district, three in the vicinity of Catskill, Greene county, and two near Hudson, Columbia county. The Alpha Portland Cement Co. operates a mill on the riverside near Smith Landing, Greene county, which was formally owned by the Catskill Cement Co. The limestone (Becraft) is taken from quarries situated on the high ledge, about one-half mile back from the river. Alsen's American Portland Cement Works are situated at Alsen, on the West Shore railroad, and close to the ledge, about a mile north of the quarries worked by the former company. A short railroad connects the plant with the docks on the river. The Acme Cement Co. started production in 1916 in the plant built by the Seaboard Portland Cement Co., between Alsen and Catskill. Its quarries are in the same series of limestone ledges and the clays are from the terraced beds of Hudson River clays. On the east side of the river in the vicinity of Hudson are the mills of the Knickerbocker Portland Cement Co. and the New York and New England Cement & Lime Co., situated on the edge of Becraft mountain, an isolated outlier of the same limestones that outcrop along the west side of the valley. The section exposed here includes the Manlius, Coeymans, New Scotland, Becraft and Port Ewen limestone beds.

In the eastern section of the State also are the mills of the Helderberg Cement Co. and of the Glens Falls Portland Cement Co. The former is located at Howes Cave, Schoharie county, where the Cayugan and Helderbergian formations provide many limestone beds, some of which are suitable for portland cement and others for natural cement. The first plant was erected to make natural cement and for a time both grades were manufactured. The present portland cement mill was erected about 1900 but has been improved and extended. Glens Falls on the upper Hudson river, where it debouches from the Adirondacks, has been the site of portland cement manufacture since 1894. It is well situated for the markets of

northern New York and the proximate section of New England. Trenton limestone and local clays are employed in the mill.

In central New York the Cayuga Lake Cement Corporation and the Millen Portland Cement Co., have been the only producers in recent years. The former operates a mill on Portland Point, 5 miles north of Ithaca, where the Tully limestone outcrops near the lakeside. Cayuga lake is connected with the canal system of the State and shipments are made both by water and rail. The Millen Portland Cement Co., erected a plant at Jamesville, Onondaga county in 1913, the last one to be built in the State. The supply of limestone is secured from the quarries of the Solvay Process Co. nearby, the smaller stone being employed for cement. The beds include the Manlius, Coeymans and lower part of the Onondaga formations.

All of the marl plants that were built in the central part of the State have been destroyed or dismantled, resulting in the loss of considerable manufacturing capacity in this section. The last of the mills to succumb was that of the Marengo Portland Cement Co., near Caledonia, Livingston county, which was dismantled in 1912.

NATURAL CEMENT

Cement rock supplies. The materials that have been used for natural hydraulic cement are impure limestones which occur in various formations of the Silurian system. They have a considerable content of clayey matter and also are usually rather high in magnesia in which respect they differ most markedly from the portland cement limestones. In the Rosendale district of Ulster county, the cement rock contains from 54 to 75 per cent of calcium and magnesium carbonates and from 20 to 40 per cent or so of combined silica, alumina and iron oxides. In central New York the typical rock runs higher in carbonates of which it contains 80 per cent or more, with 15 to 20 per cent of argillaceous impurities.

The natural cement industry had its principal center in the vicinity of Kingston, the several quarry localities including East Kingston, Rondout, Binnewater, Lawrenceville and Rosendale. The beds suitable for cement making are found in the Salina and Rondout formations and measure up to 50 feet thick. They are usually tilted at high angles, so that many of the excavations are really underground mines in which the rock is taken out in large rooms, with pillars left at intervals for support of the roof. The mines have been worked to depths of 800 to 1000 feet on the slope and 1000 feet or more along the strike. Van Ingen and Clark¹ made

¹ Disturbed fossiliferous rocks in the vicinity of Rondout, N. Y. N. Y. State Mus. Bul. 69, 1903, p. 1176-1227.

a careful study of the Rondout section and established the stratigraphic relations which are exceedingly complicated by the intense folding and faulting. In that locality 9 distinct cement layers or beds are encountered, with an aggregate thickness of 30 feet.

At Howes Cave, Schoharie county, there is a great development of limestones which include members of the Helderbergian and Cayugan groups, ranging from nearly pure calcium carbonate rocks to argillaceous strata with considerable magnesia. The natural cement rock occurs in the lower part of the section and belongs to the Rondout formation. It carries about 75 per cent of carbonates, of which 20 per cent is magnesium carbonate; the rest is silica, alumina and iron oxides.

In central New York natural cement rock has been quarried in Madison and Onondaga counties where it is found near the top of the Manlius formation of the Silurian. The quarries are located near Manlius, Jamesville and Fayetteville and at one time supported a thriving industry. The rock occurs in two layers each about 4 feet thick.

Cement quarries at Buffalo, Falkirk and Akron, Erie county, once ranked second only to those in the Rosendale district in quantity of product. The limestone is the Bertie at the top of the Salina series and the workable thickness ranges from 5 to 8 feet.

Industrial development. The first experiments in the manufacture of natural cement are recorded as having been undertaken in Madison county during the construction of the Erie canal. They resulted from the discovery that certain limestones when calcined did not slake on addition of water, but after grinding the same material developed hydraulic properties so that it could be employed under water. The quarry from which the limestone used in the experiments was taken is said to have been situated on the lands of T. Clarke, in Sullivan township, Madison county. The product of the first efforts at cement making was employed in the locks and walls of the Erie canal in the years 1818 and 1819, and soon after a patent was taken out on the basis of this discovery by Canvass White. The Legislature of the State of New York purchased the patent rights for manufacturing the cement in the State in 1825 for the use of the citizens.

Cement works were established in the Kingston district soon after the original developments in central New York, probably about 1825; the industry here was favored by natural advantages for manufacturing and marketing the product and it rapidly attained importance. By 1840 there were 16 plants with a total of 60 kilns engaged in the

business. Mather estimated the output for that year at 600,000 barrels. The height of prosperity was attained in the decade preceding 1900, when the output of this district reached a maximum of about 3,000,000 barrels a year. In 1892 the production, as given in *Mineral Resources*, amounted to 2,833,107 barrels, while the output of the State amounted to 3,786,687 barrels and of the entire country to 8,211,181 barrels. F. L. Nason¹ has supplied a list of the manufacturers for 1893, with details of the quarries and kilns operated by each and of the estimated output, which will be of interest as a record of the industry in its prime.

Manufacturers of natural cement in Rosendale district

NAME	WORKS	NO. OF KILNS	ESTIMATED PRODUC- TION 1893
Newark Lime & Cement Co. N. Y. & Rosendale Cement Co.....	Rondout..... Rosendale, Wilbur, Creek- locks, E. Kingston.....	21 30	200 000 450 000
F. O. Norton.....	High Falls.....	6	25 000
High Falls & Binnewater Cement Co.....	Binnewater.....	16	225 000
D. A. Barnhardt.....	High Falls.....	9	55 000
J. H. Vandemark.....	Bruceville.....	4	32 450
Lawrenceville Cement Co....	Binnewater.....	15	100 000
New York Cement Co.....	LeFevre Falls.....	13	290 000
Newark & Rosendale Cement Co.....	Whiteport.....	17	155 000
A. J. Snyder & Son.....	Lawrenceville.....	5	115 000
Connelly & Shaffer.....	Creeklocks.....	6	135 000
Lawrence Cement Co.....	Rock Lock, Eddyville, Bin- newater, Lawrenceville...	64	910 056

Most of the plants in the above list were later taken over by the Consolidated Rosendale Cement Co., which secured control of the larger part of the manufacturing capacity and conducted operations at the more advantageous localities. Notwithstanding the effort to affect economies in production and to increase the sales, the industry rapidly declined after 1900. In the last few years operations have been restricted to one or two mills, with only a nominal output.

Erie county once contributed a large output of natural cement from works in Buffalo and near Akron. It would appear that the

¹ Economic Geology of Ulster County. 47th Ann. Rep't, N. Y. State Mus. 1894, p. 593.

beginnings of the industry date back to 1824 when a small quantity of natural cement was made at Williamsville, but the first mill to undertake regular operations was built at Falkirk, outside of Akron in 1839. This plant was last operated by the firm of H. L. & W. C. Newman. The Cummings Cement Co. had a large plant at Akron, which ran until about 10 years ago. The Akron Cement Works also made cement here. The Buffalo Cement Co. for many years worked a quarry on Main street, near the belt line of the New York Central railroad. None of the Erie county mills have been active for several years.

In Onondaga county a number of quarries and mills were operative up to some 15 years ago, and a small quantity of natural cement is still made for the local market. A list of manufacturers quoted from Luther¹ shows the extent of the industry at about the high point, that is for 1895.

Manufacturers of natural cement in Onondaga county

NAME	WORKS	NO. OF KILNS
T. W. Sheedy.....	Near Fayetteville.....	3
Bangs & Gaynor.....	Fayetteville.....	4
J. Behan Est.....	Near Manlius.....	4
A. E. Alvord.....	Manlius.....	9
Eaton Brothers.....	Edwards Falls.....	1
R. Dunlop.....	Jamesville.....	5
E. B. Alvord & Co.....	Jamesville.....	2
Britton & Clark.....	Near Jamesville.....	7
L. H. Walker.....	Marcellus Falls.....	.....
P. C. Corrigan.....	Skaneateles Falls.....	2

PRODUCTION OF CEMENT

The total output of natural rock cement in the State since the beginning and up to the year 1916 is placed by R. W. Jones² at 119,823,000 barrels. With the addition of the figures for 1917 and 1918 the total thus may be placed in round numbers at 120,000,000 barrels.

The product of portland cement, inclusive of the figures for 1917 and 1918 has amounted roundly to 60,000,000 barrels.

¹ Economic Geology of Onondaga County. N. Y. State Mus. Ann. Rep't 49, v. 2, 1898, p. 237-303.

² Guide to the collections of General Geology and Economic Geology. 13th Ann. Rep't of Director of the N. Y. State Mus., 1917.

The following table presents the figures of cement production for the period 1890-1918; the statistics for the earlier years being those published by the *Mineral Resources*.

Production of cement in New York

YEAR	PORTLAND CEMENT		NATURAL CEMENT	
	Barrels	Value	Barrels	Value
1890.....	65 000	\$140 000	3 776 756	\$2 985 513
1891.....	87 000	190 250	3 931 306	3 046 279
1892.....	124 000	279 000	3 780 687	3 074 781
1893.....	137 096	287 725	3 597 758	2 805 387
1894.....	117 275	205 231	3 446 330	1 974 463
1895.....	159 320	278 810	3 939 727	2 285 094
1896.....	260 787	443 175	4 181 918	2 423 891
1897.....	394 398	690 179	4 259 186	2 123 771
1898.....	554 358	970 126	4 157 917	2 065 658
1899.....	472 386	708 579	4 689 167	2 813 500
1900.....	465 832	582 290	3 409 085	2 045 451
1901.....	617 228	617 228	2 234 131	1 117 066
1902.....	1 156 807	1 521 553	3 577 340	2 135 036
1903.....	1 602 946	2 031 310	2 417 137	1 510 529
1904.....	1 377 302	1 245 778	1 881 630	1 207 883
1905.....	2 117 822	2 046 864	2 257 698	1 590 689
1906.....	2 423 374	2 766 488	1 691 565	1 184 211
1907.....	2 108 450	2 214 090	1 137 279	757 730
1908.....	1 988 874	1 813 622	623 588	441 136
1909.....	2 061 019	1 761 297	549 364	361 605
1910.....	3 364 255	2 939 818	292 760	147 202
1911.....	3 416 400	2 930 434	274 973	134 900
1912.....	4 495 842	3 488 931	287 693	142 165
1913.....	5 146 782	4 873 807	193 975	95 565
1914.....	5 667 728	5 088 677	232 076	115 117
1915.....	5 219 460	4 175 528	223 564	134 138
1916.....	5 603 477	5 752 809	104 415	51 635
1917.....	5 408 726	7 050 656	57 629	41 395
1918.....	4 074 159	6 568 746	10 167	7 625

References

- Eckel, E. C. Portland Cement Materials and Industry in the United States. U. S. Geol. Sur. Bul. 522. Washington, 1913
- Lewis, F. H. Manufacture of Hydraulic Cement in the U. S. The Mineral Industry, v. 6. New York. 1897
- Ries, H. & Eckel, E. C. Lime and Cement Industries of New York. N. Y. State Mus. Bul. 44, 1901

CLAY MATERIALS

A wide assortment of clay wares is made in New York State. The list of products includes common and ornamental building brick, terra cotta, hollow blocks, fireproofing, paving brick, fire brick, drain tile and sewer pipe, and various grades of pottery. The manufacture of building materials is especially important and is carried on in nearly every section, favored by extensive deposits of clay suitable for the purpose as well as by unrivalled market facilities. This branch of the industry enjoyed great prosperity in the period from about 1895 to 1910 when building operations were notably active throughout the State; but the use of clay materials seems destined to attain even greater proportion in the future by reason of their relative cheapness, their durability and the ease with which they may be adapted to various architectural requirements.

The finer grades of clay wares are now being made in considerable quantities. Their manufacture, however, is not dependent on local materials for the most part. In contrast with the other States along the Atlantic seaboard to the south, New York possesses only scanty resources of the high-grade clays suitable for porcelain and white wares. Such deposits occur here and there, but hardly in workable quantities. The lack of kaolin and white clays may be ascribed to the work of the glacial ice which in the Pleistocene swept over practically all of the State, carrying away the deposits of residual clays and replacing them with beds of boulder clay and water-laid mixed clays.

OCCURRENCE AND CHARACTER OF CLAYS

The distribution of clays in New York, as well as their character, uses and industrial development, has been described at length in the report by Professor H. Ries, "Clays of New York" published as Bulletin 35 of the New York State Museum. The following resumé is based largely on data contained in that report.

The soft plastic clays, as distinguished from shale, have accumulated during the more recent geologic ages, ranging from the Cretaceous period to the present. The time of most widespread clay deposition was the late Pleistocene when practically all of the clays of the mainland were laid down. Cretaceous clays have a limited distribution on Long Island and Staten Island, and a few deposits on the north shore of Long Island have been referred to the Tertiary period.

The Pleistocene deposits were formed under various conditions, but in most instances as the result of glacial action or of the retreat of the ice sheet from the gradual melting of the southern margin.

Some are of morainal character and were laid down under the ice or at the ice front. They consist of stiff clays in ill-sorted layers mingled with sands, or of boulder till made up of hard blue clay in which lie all sorts and shapes of pebbles and boulders that have been ground and polished by abrasion as they were swept along by the ice. Deposits of this character have not been utilized to any extent except in one or two localities, owing to the difficulties presented by the working of the mixture of clay and rock.

Most of the clay beds that are exploited for brick-making are the result primarily of glacial action but sorted and deposited by water; they represent the rock flour and fine materials carried along with the moving ice until swept out by the subglacial streams to be finally deposited in some quiet water, perhaps at a long distance from the ice itself. Such beds are found in many valley bottoms in basin-shaped areas which are the sites of lakes and ponds formed temporarily by obstructions of ice or moraines. They are also formed in places as terraced beds along the valley that reach well above the present valley floor. In thickness they range from a few feet up to 100 feet or more. Their color normally is blue, but in the upper beds exposed to the weather they may be yellow from oxidation of the iron. Beds of fine sand are frequently interstratified with them, the alteration of the two materials taking place with marked regularity suggestive of a periodical change of the conditions of deposit. The Hudson and Champlain valleys were flooded to a great depth in late Pleistocene, so that deposits of clay occur in terraces that extend from the present water levels to several hundred feet above.

Long Island. Clay beds outcrop along the north shore and at several points on the main line of the Long Island railroad. The common brick clays of Pleistocene age extend in patches almost the entire length of the island. They are generally intermixed with gravel and boulders, so that sorting and crushing are necessary before used in brick machines. The deposits do not reach any great thickness and have to be worked in pits rather than banks. The depth of the pits is usually 10 or 12 feet. The Cretaceous clays are somewhat sandy in character. Some are adapted for stoneware and the coarser pottery. The more sandy beds require very little preparation for brick making, and in some yards are used without the addition of sand. Elm point, near Great Neck, has been a source of stoneware clay. Other deposits of Cretaceous clays are found on the east shore of Hempstead harbor, at Glen Cove, on Center island in Oyster bay, on Little Neck in Northport bay and other localities. Brick yards have been operated at Garden City, East Williston,

Farmingdale, Port Jefferson, Southold, Greenport and on Center island and Fishers island.

On Staten Island Cretaceous clays, some of which are light in color, occur in the southern section around Tottenville. They are too siliceous, however, to be used in pottery, and have been employed in terra cotta, fire brick, ornamental brick, etc. Stony clays of Pleistocene age are found at Green Ridge and on the shore of Arthur kill, where brick yards have been operated.

Hudson valley. The valley of the Hudson from Mechanicville south to Westchester and Rockland counties constitutes the great brick-making region of the State and in fact the most important district in the entire country. The clays are water-sorted glacial materials, laid down in the Pleistocene flood valley known as Lake Albany. They are found on either side of the river in terraces that reach to an extreme elevation on the north of about 400 feet above tide water and extend for a few hundred feet to several miles back from the present channel. They are covered by a mantle of sand, or occasionally of gravel, which was the last of the deposits in Lake Albany. At the base they rest upon a water-bearing sand, unsorted morainal materials or directly upon rock which is generally the Hudson River shale.

The clays attain a maximum thickness of 100 feet or somewhat more. They are divided into layers or seams, with partings of fine sand that is very similar to the sands overlying the beds. The sand parting is usually scarcely more than a film, while the clay layers themselves are often only a fraction of an inch thick. In a fresh opening, as is supplied by the many banks where the clays are dug for brickmaking, the layered appearance of the clays is very noticeable on close examination, although it becomes obscured quickly by exposure of the clays to the weather. The significance of the bedded structure has not been explained, but it invites inquiry from the standpoint of the possible relation to fluctuations in the supply of sediment that may have been governed by seasonal or diurnal changes, as suggested by the remarkable regularity in the succession of clay and sand.

The upper beds, representing a section of a few feet usually but in some places as much as 30 feet, consist of brown or yellow clay which has been shown by R. W. Jones¹ to be the weathered and leached equivalent of the blue clay below. In comparison with the latter the yellow clay contains smaller amounts of the more soluble constituents—calcium, magnesium, sodium and potassium. The two grades react somewhat differently to physical tests. The ordi-

¹N. Y. State Mus. Bul. 178, p. 27.

nary blue clays require about 29 per cent of water to make them sufficiently plastic for brick manufacture by the soft-mud method. They shrink by air drying about 6 per cent, and when burned at cone I (about 1150° C) show no fire shrinkage. The burned product is a relatively soft brick of pink color. In working the brown clays about 26 per cent water is necessary and the air shrinkage is 7.5 per cent. At 1150° C they show a fire shrinkage of 1.5 per cent and give a dense vitreous product of red color.

As a variation of the blue brick clays that are found along the middle section of the Hudson valley, the Albany slip clay presents some features of interest. Its occurrence is not distinguished by any local characteristics different from those surrounding the brick clays, in fact the two occur together. The slip clay is an exceptionally soft "greasy" type of the blue clay in which the sandy partings are reduced to a minimum. The two can hardly be differentiated, however, by physical appearance alone, and actual tests are required to determine whether a particular bed is slip clay or not. From a number of chemical analyses Jones¹ found that the principal difference in composition lies in the alumina content which is lower for the slip clays. There is, however, a considerable range in this respect among different samples obtained in the same locality, the percentages of aluminum oxide varying from 11.80 to 15.65 per cent in five samples taken from an Albany bank. The clay is worked mainly in the vicinity of Albany, and seems to be restricted in occurrence to a stretch of a few miles above and below that city which lies near the middle of the old Mohawk delta, where the clays attain their maximum areal development. Its use as a slip in glazing pottery wares is best known. Much of the domestic stoneware is thus glazed. Electric insulators for high-tension transmission lines are often glazed with slip clay. A mahogany color is usually sought for in glazes and is natural to some of the Albany clay. A larger use for the clay has developed in the manufacture of carborundum and emery wheels; the granular abrasives are mixed with a small proportion of slip clay and then molded into forms, after which they are fired. The slip clay is preferred to other clays for the purpose on account of its low fusion point.

Brick manufacture is carried on in the Hudson valley by the soft-mud process, and in 1915 the canvass conducted by this office showed a total of 127 such yards located along the river from Saratoga county to Westchester and Rockland counties. The combined capacity is well over a billion brick a year. In 1906 the

¹ Op. cit. p. 28.

high mark of 1,230,692,000 was reached, with 131 yards in operation. The leading centers of the industry are Mechanicville, Albany, Hudson, Catskill, Saugerties, Kingston, Roseton, Dutchess Junction, New Windsor, Verplanck, Stony Point and Haverstraw.

Hollow blocks and fireproofing are made from the Hudson River clays at Troy. The weathered or yellow clay is employed with a mixture of grog. No special difficulty is experienced in the molding and burning of the wares, contrary to the opinion that seems to be current that the clays can not be successfully handled except by the prevailing methods of molding soft and burning in scove kilns.

Lake Champlain. The deposits are somewhat similar to those in the Hudson valley. Terraces occur along the lake from Whitehall at the southern end to beyond the state line. They are of variable width, narrowing southward where the Adirondack ridges rise steeply almost from the shore line. At the lower end of the lake the deposits seem to be of marine character and were laid down on the receding shores of the arm of the sea which invaded the valley after the withdrawal of the glacial waters. At Westport and Port Kent the section shows yellowish brown sand, brown clay and stiff blue clay, the latter being calcareous. The beds have a thickness of 15 feet. The clays are used for brick, most of which have been made in the vicinity of Plattsburg.

Interior of the State. In the Mohawk valley clay beds of limited areal extent occur at intervals between Rome and Schenectady. They range from 5 to 15 feet thick and are red, blue or gray in color. They have been employed for common brick and hollow brick. The largest output is made in the Deerfield yards near Utica.

Clay beds underlie many of the valleys in the central and southern parts of Onondaga county. Many of them possess a red color, from admixture perhaps with the Vernon shales that reach across the county in an east-west belt on a line with Syracuse. A stiff red clay is found at the south end of the Onondaga valley. On the east bank of the Seneca river, east of Baldwinsville, blue and buff clays have been dug. The exposed thickness is from 15 to 25 feet. Stoneware clay has been obtained in years past at Belle Isle, a few miles west of Syracuse. The range of products that have been made from the local clays include common brick, paving brick, hollow blocks, drain tile and earthenware. Porcelain electric supplies and table china are made in the Syracuse potteries, but the crude materials are obtained from other sources, mainly outside of the State.

Around Rochester clay is found over an area extending 7 miles

north and south and 10 miles east and west, in the towns of Brighton, Henrietta and Chili. It is usually of reddish color and has an extreme depth of 10 or 12 feet. The main pits are in the vicinity of Rochester. Common brick, fire brick, building tile, fireproofing and drain tile have been made in the yards.

The clays of Buffalo and vicinity are the basis of an extensive brickmaking industry, the largest west of the Hudson river. The clays are described by Ries as boulder clays and modified glacial beds, varying from a foot or less to 60 feet thick. A section on Grand island showed 20 feet of red clay and 14 feet of boulder clay. There are deposits at Tonawanda and La Salle, and along the shore of Lake Erie south of Buffalo. Besides common building brick the local works have produced pressed brick, hollow brick, earthenware and drain tile. Pottery is made in Buffalo from foreign clays and ornamental brick from the Hamilton shales.

Clay is worked at Jamestown and Dunkirk, Chautauqua county. At the latter locality the deposit is 20 feet thick, consisting of yellow sandy clay on top and blue clay underneath.

In the southern part of the State the clays are of comparatively little economic importance. A small output of building brick has been made at Binghamton, Horseheads, Ithaca and a few other localities. The shale formations, however, are of more value, and will be described under a separate head.

In Jefferson and St Lawrence counties scattered deposits of clay occur that have been used for common brick manufacture in Watertown, Carthage and Ogdensburg. At Watertown a deposit 20 feet thick consists of red and gray clays resting on Trenton limestone.

OCCURRENCE OF SHALE

In addition to soft plastic clays New York has immense and widely distributed resources of shales, some of which are adapted to the manufacture of vitrified paving brick and ornamental brick. A discussion of the possibilities of the shales for paving brick will be found in Bulletin 174 of the New York State Museum.

The Devonian formations that outcrop in the southern half of the State, between a line drawn from Albany to Buffalo and the Pennsylvania border, include several important shale formations, notably in the Hamilton, Portage and Chemung groups. The shales are exposed in belts with an east-west trend and contain interbedded layers of sandstone which is quarried in many places for flagstone, building stone, etc. Splendid exposures are to be found in the

transverse stream valleys and along the shores of the Finger Lakes which occupy deep trenches in the Devonian rocks. The shales show a considerable range of composition, some being very siliceous with relatively small proportions of clay substance, and others are normal clay shales. Their utility is a matter for local investigation of conditions and practical tests. In many places they have been found to make an excellent paving brick, quite as good as the material made from fire-clays of Pennsylvania, Ohio and Michigan. Among the localities where the shales have been used for brick are Angola and Jewettville, Erie county; Jamestown, Chautauqua county; Olean, Cattaraugus county; Alfred center, Allegany county; Corning and Hornell, Steuben county; Newfield, Tompkins county; Binghampton, Broome county; and Catskill, Greene county.

The Hudson River shales which outcrop along the Hudson above the Highlands are usually hardened slaty materials developing little natural plasticity when ground. Some phases are high in silica, while the lime and iron content may be high. They have not been employed in brick manufacture, although the more argillaceous types which occur here and there might serve in mixture with the plastic local clays for the purpose.

The Salina, Clinton and Medina formations contain much shale, but in general it is not of a commercial grade.

The physical properties of the Devonian shales with reference to their adaptability to brick manufacture have been studied by Prof. H. Ries.¹ The following analyses of shale samples from different localities of the State will indicate their general chemical nature.

	1	2	3	4	5	6	7
SiO ₂	52.30	57.79	64.45	53.20	65.15	58.44	64.30
Al ₂ O ₃	18.85	16.15	17.77	23.25	15.29	} 27.45	33.60
Fe ₂ O ₃	6.55	5.20	7.04	10.90	6.16		
CaO.....	3.36	2.73	.58	1.01	3.50	1.16	1.46
MgO.....	4.49	4.67	1.85	.62	1.57	2.23	1.30
K ₂ O.....	4.65	4.11	2.52	} 2.69	5.71	.....	.....
Na ₂ O.....	1.35	1.22	1.95		.....	.....	.....
CO ₂	3.04	3.42	.....	.....	.....	.....	.....
H ₂ O.....	5.30	4.50	.....	6.39	.....	.....	.....
Total...	99.89	99.79	.....	a 99.90	.....	.....	.....

a Total also includes sulphuric acid, .41; titanio oxide, .91; manganese oxide, .52.

¹ Physical Tests of the Devonian Shales of New York. N. Y. State Mus., 49th Ann. Rep't, v. 2, 1895.

- 1 Salina red shale, Warners, Onondaga county, Analysis supplied by Onondaga Vitrified Brick Co. N. Y. State Mus. 49th Ann. Rep't, v. 2, p. 692.
- 2 Salina blue shale, Warners, Onondaga county, idem.
- 3 Chemung shale, Hornell. Analysis supplied by Hornellsville Brick Co. op. cit.
- 4 Chemung shale, Alfred Center, Allegany county. Analysis supplied by Celadon Terra Cotta Co. op. cit.
- 5 Portage shale, Angola, Erie county, op. cit.
- 6 Hamilton shale, Portland Point, Cayuga county. U. S. Geol. Surv. Bul. 522, p. 291.
- 7 Hudson River shales, Hudson, N. Y. op. cit.

THE CLAY INDUSTRIES

Clay-working plants are widely distributed over the State and their products include a large variety of wares. Brickmaking is the largest branch, both in regard to the number of enterprises and the value of their aggregate annual output. Common building brick constitutes the main item of production, but front and ornamental brick and vitrified paving brick are manufactured in smaller quantities. Next to this branch in importance is the pottery industry which accounts for a considerable proportion of the annual total, and has shown such progress in the last few years that it promises to become the leading department in regard to value of the product although restricted to a few centers and dependent largely upon outside supplies of raw materials.

The accompanying table exhibits the figures of production for the leading branches, as well as the aggregate output for the entire industry during the period 1904-1918. The figures for the last three years were compiled by this office in cooperation with the United States Geological Survey; for the earlier years they were collected by this office independently by canvass of the whole trade.

Production of clay materials

YEAR	COMMON BRICK	PAVING BRICK	TERRA COTTA	POTTERY	OTHER KINDS	TOTAL
1904.....	\$7 234 876	\$210 707	\$798 028	\$1 438 634	\$1 822 459	\$11 504 704
1905.....	9 751 753	180 004	874 717	1 620 558	1 852 984	14 280 016
1906.....	9 302 165	178 011	1 037 387	1 795 008	1 642 729	13 955 300
1907.....	7 201 525	184 306	1 224 300	2 240 895	1 837 842	12 688 868
1908.....	5 064 191	211 289	709 360	1 653 241	1 280 777	8 918 861
1909.....	8 009 766	207 970	962 497	1 827 193	1 344 056	12 351 482
1910.....	6 563 212	333 511	1 062 017	2 136 518	1 423 724	11 518 982
1911.....	5 310 511	307 529	718 700	2 196 054	1 218 865	9 751 659
1912.....	6 666 945	382 984	1 139 291	2 876 762	977 113	12 043 095
1913.....	5 938 922	576 970	1 113 322	3 367 187	1 081 471	12 077 872
1914.....	4 597 856	680 226	892 630	2 405 676	898 831	9 475 219
1915.....	4 886 734	382 502	647 815	3 064 274	1 021 048	10 002 373
1916.....	6 433 266	204 209	714 041	3 344 672	1 058 824	11 755 012
1917.....	5 068 028	248 506	813 112	4 076 817	1 221 936	11 428 399
1918.....	3 050 037	113 395	426 724	6 047 472	1 255 326	10 892 954

The statistics evidence the changing conditions in the industry from year to year. The aggregate value of clay wares has averaged about \$12,000,000 throughout the period, but has fallen considerably below that figure occasionally in times of severe depression as in 1908 and 1911, when the building trades were almost at a standstill, and again in 1914 when the outbreak of the war caused a severe decline of industrial activity. The notable feature of the statistics, which marks apparently a fundamental change in progress at present, is the increase of the higher-grade wares by which alone the diminished outputs of the commoner grades have been counterbalanced in their effect upon the annual totals.

In 1917 there were 170 enterprises who reported a production or sale of clay products for that year. In 1918 the number was 147. Both years showed a falling off in the number of enterprises from that of 1916, when 182 reported sales or production. The last two seasons were unprecedented in severity of conditions for the operators, who were unable to secure the necessary labor or fuel to conduct work on the normal basis. The most prosperous years of the industry, so far as widespread activities are concerned, were 1905, 1906 and 1907, when the number of operative plants reached a maximum of 265 and were distributed over 48 counties of the State.

Brick manufacture. The brick-making industry is carried on more widely than other branches of clay manufacturing and is represented in practically every section where a local demand exists for the product. Inasmuch as the clays are adapted mainly for the common grades of brick, the enterprises are practically dependent upon the nearby markets for outlet. They are located therefore in the vicinity of the larger towns and cities, but particularly along the tidewaters of the Hudson which give ready access to the towns on that river and also to the great metropolitan district, the largest market for building materials in the country.

Production of common building brick in New York

YEAR	QUANTITY	VALUE	VALUE PER THOUSAND
1904.....	I 275 859 000	\$7 234 876	\$5 67
1905.....	I 493 459 000	9 751 753	6 53
1906.....	I 575 434 000	9 302 165	5 98
1907.....	I 351 591 000	7 201 525	5 33
1908.....	I 056 769 283	5 064 194	4 79
1909.....	I 507 126 000	8 009 766	5 31
1910.....	I 396 606 000	6 563 212	4 70
1911.....	I 066 982 000	5 310 511	4 98
1912.....	I 190 374 000	6 666 945	5 61
1913.....	I 090 506 000	5 938 922	5 45
1914.....	932 759 000	4 597 856	4 93
1915.....	934 726 000	4 886 734	5 22
1916.....	977 085 000	6 433 266	6 59
1917.....	656 508 000	5 068 028	7 72
1918.....	313 638 000	3 050 037	9 72

Altogether there are probably 175 yards equipped for making brick, although the number actually operated in the last few years has fallen considerably short of that figure, owing to a combination of conditions. In 1906 there were 213 plants engaged in the common brick industry of which 131 were situated in the nine counties comprising the Hudson River district. With the decline of demand which has manifested itself in the last decade a considerable number of yards have been dismantled.

There has been less change or improvement in methods of brick making than in almost any other branch of the mineral industry carried on within the State. Nearly all of the common brick are made by soft mud machines, dried largely in open yards and burned in scove kilns. These methods are wasteful of labor, fuel and also of product, of which a considerable share consists of rain-washed and underburned brick, under the best circumstances. It is commonly held that the soft plastic clays, like those in the Hudson valley, are scarcely amenable to any other process, but this should not be accepted as a general principle without actual working tests, since there is known to be a great deal of variation in the character of the clays within a single district.

In the Hudson River region which includes the strip on both banks from Albany and Rensselaer counties south to Rockland and Westchester, the output in a normal season has amounted to 1,000,000,000 brick and in some years has ranged well above that number. In 1906 for example, it was 1,230,692,000, probably the

largest outturn up to the present. The capacity of the yards may be placed at about 10,000,000 a day, the output of nearly 500 soft-mud machines. The chief districts are in the vicinity of Haverstraw, Dutchess Junction and Kingston. There are over 20 yards in the Haverstraw district which extends from the southern limits of the town north through Grassy Point and North Haverstraw, a distance of about 3 miles. Nearly one-third of the capacity of the whole Hudson River region is represented in this district. The clay is obtained from pits and banks just back of the river shore and by dredging the bed of the river itself, the latter practice being employed by four yards. At Dutchess Junction there were until recently 16 yards and their capacity was about one-fifth of the total for the district. The Kingston district stretches along the river front above and below that city for 12 miles, including yards at Port Ewen, Kingston, East Kingston, Glasco, Saugerties and Malden, with a capacity nearly equal to that of the Haverstraw district. According to R. W. Jones who has supplied most of these particulars, the yards now use coal largely for firing the arches in the place of wood which has become too expensive for the purpose; the open yard is favored for drying, although pallets, covered yards and steam tunnels are to be found in the district. The brick are mostly shipped to New York, the output in Albany and Rensselaer counties alone being largely marketed locally. Barges are used for transport.

Output of common brick in the Hudson River region for 1916

COUNTY	NUMBER OF OPERATORS	OUTPUT	VALUE	PRICE PER THOUSAND
Albany.....	11	71 183 000	\$442 640	\$6 21
Columbia.....	4	59 415 000	350 771	5 90
Dutchess.....	14	87 779 000	552 271	6 29
Greene.....	5	29 683 000	182 524	6 14
Orange.....	7	80 450 000	577 829	7 18
Rensselaer <i>a</i>				
Rockland.....	19	121 967 000	809 019	6 63
Ulster.....	22	222 651 000	1 444 275	6 43
Westchester.....	3	18 357 000	126 197	6 87
Total.....	85	691 485 000	\$4 485 526	\$6 48

a The output of Rensselaer county is not included with that of the Hudson river counties, having tidewater transportation.

Output of common brick in the Hudson River region in 1917

COUNTY	NUMBER OF OPERATORS	OUTPUT	VALUE	PRICE PER THOUSAND
Albany.....	12	50 774 000	\$376 431	\$7 41
Columbia.....	5	32 618 000	261 320	8 01
Dutchess.....	11	56 740 000	411 681	7 26
Greene.....	5	23 861 000	138 197	5 79
Orange.....	5	61 083 000	441 790	7 23
Rensselaer <i>a</i>	2	.....	.....	.....
Rockland.....	20	89 227 000	668 197	7 49
Ulster.....	20	142 768 000	1 040 535	7 29
Westchester.....	5	9 973 000	85 422	8 57
Total.....	85	467 044 000	\$3 423 573	\$7 33

a The output of Rensselaer county is included with that of Albany county.

Output of common brick in the Hudson River region for 1918

COUNTY	NUMBER OF OPERATORS	OUTPUT	VALUE	PRICE PER THOUSAND
Albany.....	11	27 453 000	\$290 935	\$10 60
Columbia.....	5	15 372 000	145 367	9 46
Dutchess.....	10	28 376 000	256 918	9 05
Greene.....	5	9 875 000	93 405	9 46
Orange.....	4	14 775 000	123 177	8 34
Rensselaer <i>a</i>	2	.....	.....	.....
Rockland.....	13	29 994 000	267 972	8 93
Ulster.....	14	81 332 000	735 140	9 04
Westchester.....	2	4 397 000	37 697	8 58
Total.....	66	211 574 000	\$1 950 611	\$9 22

a The output of Rensselaer county is included with that of Albany county.

At Mechanicville, Saratoga county, there is a smaller center of brickmaking, based on the Hudson valley clays, which is supported mainly by the New England market. The same methods are employed as farther south. Five yards are in existence of which three have been recently active.

Outside of the Hudson valley the principal centers are at Utica, Syracuse, Rochester and Buffalo and vicinity, of which the last has the largest production. Soft clays are not so abundant and the use of shale, either alone or in mixture with clay, has been adopted

by some of the Erie county yards. The latter make wire-cut brick and have permanent kilns.

Front brick are made in comparatively small numbers, and it is in this branch that the greatest opportunity for development seems to lie. At present most of the ornamental brick are brought from Ohio, Pennsylvania and more remote states, although materials are at hand that could be used for their manufacture in local yards. Some of the shales are well adapted to the purpose and are being used successfully by a few plants. The following statement by R. W. Jones¹ is also of interest in this connection. "There is found along the Hudson river in certain localities a heavy bed of light brown laminated clay having a low fire shrinkage and comparatively high fusing point. This clay without the addition of any other substance, burns to a dark red color and when formed in the auger machine gives a perfectly smooth surface. It is not necessary to add sand in tempering with the present mining equipment and with a small addition in the way of auger machines and kilns at a few of the present Hudson river yards there could be turned out an immense quantity of first-class, smooth-face red front brick for the New York market."

Fireproofing. The production of this material has shown a fairly steady growth in the last ten years and has become an item of considerable importance in the list of manufactures. The material is known under the various names of terra cotta lumber, hollow tile, hollow building block, as well as fireproofing which may serve as the collective term. It includes a variety of shapes and sizes that are used in the construction of side walls, floors, arches and partitions, but usually one of the faces has an area of 1 square foot. The product is mainly sold by the ton, but for small quantities the prices may be quoted by the square foot. The number of air spaces varies from one to nine. According to R. W. Jones², the material in New York State is made by the stiff-mud process. Both clays and shales are used, either separately or mixed, depending upon local conditions. While the clays of the Hudson valley are not usually suitable for the manufacture of stiff-mud wares, there are local beds, especially among the delta deposits, that can be employed for the purpose. Such deposits occur near the mouth of the Mohawk river and are utilized for the manufacture of both fireproofing and common hollow brick. The calcareous clays of the western part of the State are also used and the shales in some sections seem to

¹ N. Y. State Mus. Bul. 190, p. 22, 1916.

² N. Y. State Mus. Bul. 174, p. 22, 1914.

be well adapted to its manufacture. The preparation of the soft plastic clays consists first in passing them through a disintegrator without water. Coal screenings, sand, and grog of crushed burned brick may be added at this point. The mixture then goes to a set of rolls, through a pug mill and finally to the machine, which is generally a horizontal auger type, but may be a tile press. Shales are usually pulverized in a dry pan, water added to the ground material which then is finished in a wet pan as substitute for the pug mill. Drying is performed by steam, waste-heat, or direct-heat tunnels, and also in covered pallet yards. The product is burned in down-draft kilns with bituminous coal for fuel. The burning requires about 5 days.

The production of fireproofing has been carried on in recent years at eight plants, of which three are in Erie county and one each in Monroe, Livingston, Rensselaer, Niagara and Kings counties. The output has varied considerably from year to year with the activity in building operations and in the last three seasons naturally has shown a tendency to decline. The value for 1914 was \$245,034, for 1915 \$177,844, for 1916 \$174,786, for 1917 \$140,464 and 1918 \$174,974.

Paving brick. The manufacture of paving brick is one of the branches of the clay-working industries that has shown evidences of substantial growth in recent years, although it received a setback with the outbreak of the war and consequent suspension of active road building throughout the State. The first paving brick were made in 1888 at Elmira. Since then plants have been erected at several other localities, namely, Binghamton, Corning, Hornell, Jamestown, Newfield, Syracuse and Catskill. The maximum output was recorded in 1914, when the returns showed 46,696,000 brick valued at \$680,226. In the following year owing to conditions brought about by the war the output fell to 26,154,000 worth \$382,502. In 1917 it was 12,906,000 with a value of \$248,506. The 1918 production was 4,784,000 valued at \$104,764.

The materials most commonly employed for paving brick are fire-clays, but in their absence the Devonian shales have been tested out and certain occurrences found to be well adapted for the purpose. The shales belong to the Hamilton, Portage and Chemung formations which outcrop in belts extending east and west across the central and lower tiers of counties as far south as the Pennsylvania state line. There are many places where the shales outcrop in force under conditions favorable to their excavation and use, but they do not all possess the necessary physical and chemical properties so that

working tests are necessary to establish the value of the shales of any particular locality. The existence of these resources in the southern section of the State may prove of greater importance in the future than in the past; they seem to be the most available local material for road construction as there is a dearth of good stone in that region.

The shales in some places are worked up alone, having sufficient plasticity when ground to make brick. When this quality is lacking a certain proportion of plastic clay is admixed with the shale. The following description of the methods in current use has been taken from an article by R. W. Jones in the *Mining and Quarry Industry* for 1913:

"In nearly all cases the material receives a preliminary crushing in jaw or gyratory crushers before it is sent to the dry pan. It is reduced in the dry pan to a size that will pass a 3-16 inch mesh, then screened and the oversize returned to the pan for further grinding. The pulverized material then goes to the storage bins. The dry pan consists of a revolving slotted or perforated iron plate having a rim about one foot in height around the side. Two heavy iron mullers resting on edge, revolving by friction against the bottom plate, crush the material.

"From the storage bins the pulverized material goes to the pug mill where the necessary water is added to form a stiff mud. The pug mill consists of a semicylindrical, horizontal trough of metal through the center of which revolves a shaft, furnished with steel arms so set as to mix thoroughly the dry material and water and to feed it continually forward to the brick machine.

"The brick machine, generally known as the auger machine, consists of a heavy tapering steel barrel set directly under the pug mill or combined with the pug mill on a single base. The material from the pug mill is forced by the auger under great pressure through this tapering barrel and issues from a die at the end in a solid column, the size depending upon the method to be used in cutting. With side-cut bricks the column has a cross section of about $4\frac{1}{2}$ by 10 inches and with end-cut bricks 4 by $4\frac{1}{2}$ inches. The column of stiff mud is forced along over a cutting table where it is cut by means of piano wire into bricks of such dimensions that, allowing for repressing, drying and burning, will produce a finished product of a standard size. Twelve bricks are usually made at one cut. From the cutting table the product is taken by a continuous belt either to the represses or direct to the double-deck cars preparatory

to drying. Lugs are a necessity on paving bricks and are either formed by the process of repressing or at the time of cutting.

"The product now goes to the drying tunnels where a temperature sufficient to dry the bricks in about 24 hours is secured either by the use of steam, waste heat from the kilns, or by direct heat. The bricks lose in moisture about 20 per cent of their original weight in the process of drying. The cars have a capacity of from 450 to 500 bricks and traverse a distance of about 100 feet between the time of entering and leaving the drying tunnels.

"Burning, which is probably the most important branch of the industry, is carried on in down-draft or in continuous kilns, using bituminous or anthracite coal with or without a forced draft. Kilns and methods of burning vary. The kiln in most common use, known as the rectangular down-draft kiln, has inside dimensions of about 80 feet in length by 18 feet in width and $12\frac{1}{2}$ feet in height with ten or more fireplaces on each side. The fireplaces are built in such a manner that the heat reaches the top of the kiln first, passes down through the green brick, then through the floor and by a system of flues to the stack. The proper burn is recognized almost entirely by the settle of the brick. Kilns are set about 27 bricks high, the bricks separated from each other by a thin layer of sea sand, and burned from 10 to 12 days until the material settles from 12 to 15 inches. On account of the difference in kiln temperature between the top and bottom it is the usual custom to set the first two to six layers with either common, side-walk, or rough-faced front brick that do not require so high a temperature to burn as do the paving brick.

"A circular down-draft kiln is also used in the burning of paving brick. The kiln, in this case, has an inside diameter of from 20 to 30 feet and a height of about 14 feet, and is usually furnished with eight fireplaces having individual stacks or all drawing to one stack. It would seem from experience that the circular down-draft kiln has some advantages in temperature regulation. The continuous kiln in use for the burning of paving brick, in this State at present, is of the Haight type. This consists in form of two rectangular kilns placed in a parallel position and connected at both ends by a semicircular extension of the same cross section. The kiln is divided into fifty-five chambers and after the original fire is started it is a continuous operation of setting, burning, cooling and emptying. This kiln is top fired, using bituminous coal, the fire being controlled and regulated by dampers. The waste heat in cooling is carried over to a forward chamber and assists in drying. As soon as a

compartment is burned, the fire is transferred ahead to the next and the first begins to cool. In this manner, the fire is carried completely around the kiln."

Pottery. Pottery has been made in New York since early times. It was probably one of the first branches of the clay-working industry introduced by the colonists, although there is little specific information to be had in regard to the early beginnings of pottery manufacture. It is certain that the first efforts in this line did not extend beyond the production of common wares like earthenware and stoneware which required no considerable plant or technical equipment. Clays suitable for pottery of this sort were dug in certain localities within the State or were brought in from New Jersey and other sources. One of the best slip clays for the glazing of stoneware is to be had in Albany, and no doubt the deposit had something to do with the location of potteries in that vicinity which carried on active business up to a few years ago.

White wares as articles of manufacture did not receive attention from local potteries until about the middle of the 19th century. The present diversified industry, which covers nearly every department of the ceramic arts so far established in this country, has been a development practically of the last three or four decades. A factory for making bone china was established in Brooklyn in 1854, probably the first of its kind. This later became the Union Porcelain Works which took up the manufacture of porcelain ornamental and table wares; the plant is still active. A pottery for granite ware was located in Syracuse in 1871 and about 1886 the Onondaga Pottery Co., the owners, converted it into a pottery for china wares; it ranks as one of the large and successful establishments of the kind in the country. The Iroquois China Co. of Syracuse also manufactures china tablewares, and in Buffalo is the Buffalo Pottery, a producer mainly of white ware.

Porcelain electrical supplies constitute one of the largest items of the list of pottery wares, and in this branch New York shares with one or two other states the leadership in regard to value of the annual outturn. The list of manufacturers include the Empire China Works and the Union Porcelain Works, Brooklyn; Pass & Seymour, Inc., Syracuse; Locke Insulator Manufacturing Co., Victor; Lapp Insulator Co., Inc., Leroy; Weber Electric Co. and the General Electric Co., Schenectady.

The manufacture of earthenware and stoneware has not been very active in the last few years. The Syracuse Pottery is the principal producer in this line.

Among the miscellaneous articles which have been made by New York potteries in recent years are art wares, delft, chemical and sanitary wares, and tobacco pipes.

The pottery production for 1917 was valued at \$4,076,817, about one-half of which represented the value of porcelain electrical supplies (\$2,018,363) and over one-third of the total consisted of china table wares (\$1,574,962). In 1918 the pottery production amounted to \$6,047,472, of which \$3,595,478 is credited to porcelain electrical supplies.

References to clay

- Beck, Lewis C.** Mineralogy of New York. 1842
- Bishop, Irving P.** Structural and Economic Geology of Erie County. N. Y. State Mus. 49th Ann. Rep't, v. 2, 1898
- Hall, James.** Geology of New York. Survey of the Fourth Geological District. 1843
- Jones, R. W.** The Manufacture of Paving Brick in New York State. N. Y. State Mus. Bul. 174, 1914, p. 23-31
- Luther, D. Dana.** Economic Geology of Onondaga County. N. Y. State Mus. 49th Ann. Rep't, v. 2, 1898
- Nason, F. L.** Economic Geology of Albany County. N. Y. State Mus. 47th Ann. Rep't, 1894
- Ries, H.** Clays of New York, Their Properties and Uses. N. Y. State Mus. Bul. 35, 1900
- Physical Tests of the Devonian Shales of New York State to Determine their Value for the Manufacture of Clay Products. N. Y. State Mus. 49th Ann. Rep't, v. 2, 1898
- Quaternary Deposits of the Hudson River Valley between Croton and Albany, etc. N. Y. State Geologist 10th Ann. Rep't, 1891, p. 110-55
- Geology of Orange County. N. Y. State Mus. 49th Ann. Rep't, v. 2, 1898
- Woodworth, J. B.** Pleistocene Geology of Nassau County and Borough of Queens. N. Y. State Mus. Bul. 48, 1901

DIATOMACEOUS EARTH

Diatomaceous earth is a finely divided earthy substance that closely resembles chalk or marl in appearance but has a base of silica instead of lime carbonate. It is an accumulation of the skeletal remains of minute organisms (diatoms) that live in fresh lakes and ponds. It is sometimes called tripoli, but the two should not be confused, as tripoli is a siliceous earth formed by the decomposition and breaking down of impure limestones and hence of inorganic derivation like rotten stone. It is a very light, porous, usually white material that occurs in powdery or slightly coherent condition. Chemical analysis shows the presence of considerable water combined with the silica, so that it differs from ordinary quartz and is

classed by mineralogists with the opal varieties of silica. The better grades of diatomaceous earth contain not more than 2 per cent of impurities in the form of iron oxides, alumina and lime, with 85 per cent or more silica, the rest being water.

Uses. By reason of its hardness and uniform fineness of grain diatomaceous earth makes a good abrasive. It is extensively employed in polishing powders and scouring materials for metals. According to Frank J. Katz in an article in the *Mineral Resources* for 1915, its uses have been considerably extended of late, so that the demand for it has steadily grown. Among the different functions which it serves are as a filtering agent, as an insulator for steam pipes, boilers and in fireproofing, as an ingredient of phonographic records, as an absorbent in artificial fertilizers and as a base for the manufacture of water glass. It has been employed also in the production of cements, glazes, artificial stone, paints and pigments, fireworks, matches and various other commodities.

Occurrence. The principal deposits of diatomaceous earth are found in the Adirondack lakes. Most is known of the deposits in Herkimer county, which have been reported upon by Charles F. Cox, as noted in the appended list of references. One of the localities, White Lead lake, in southern Herkimer county has been known for many years and has been the source of considerable quantities of the material for commercial use. The deposit in that lake is said to cover an area of about 4 acres and to have a thickness of from 2 to 30 feet. It lies below 4 feet of water. The material after excavation is purified by washing and settling in vats, then compressed and dried. The Adirondack Diatomaceous Earth Co. has worked the deposit in recent years. An analysis by Dr Gideon E. Moore, as reported by F. J. H. Merrill showed the following composition.

SiO ₂	86.515
Al ₂ O ₃	.449
Fe ₂ O ₃	.374
CaO	.120
H ₂ O and Volatile	12.120
Undetermined	.422

100.000

Construction work on the Mohawk & Malone Railroad about the year 1892 brought to notice several occurrences in northern Herkimer county. The localities for diatomaceous earth in that section include Clear lake, Big Crooked lake, Hawk lake, Chub lake, Roilly pond and one or two unnamed ponds, which altogether hold an immense quantity of the material. The deposit in sight in White

Lead lake has been estimated at 100,000 cubic yards and that in Clear lake at about the same amount; the deposits in Roilly pond and Big Crooked lake, according to Mr Cox, may contain over 1,000,000 cubic yards each. About 5 acres of the filled lake or Beaver meadow west of Big Crooked lake is said to be covered by a deposit from 2 to 12 feet thick, with an average depth perhaps of 3 feet. Overlying this bed is about 1 foot of soil and vegetable matter. The earth at all the localities consists of an aggregate of different kinds of diatoms, mostly of the unattached or free forms. The ponds and lakes came into existence after the retreat of the Pleistocene ice-sheet.

According to F. J. H. Merrill, diatomaceous earth is present on the shore of Cold Spring Harbor, Long island, notably on property owned by Dr Oliver Jones. It is stated to be of fossil nature, as it occurs in beds that are regarded as Tertiary in age.

References

- Cox, Charles F. On Recently Discovered Deposits of Diatomaceous Earth in the Adirondacks. N. Y. Acad. Sci. Trans., v. 12, 1893, p. 219-20
——— Additional Notes on Recently Discovered Deposits of Diatomaceous Earth in the Adirondacks. Op. cit., v. 13, 1893, p. 98-101
Merrill, F. J. H. Mineral Resources of New York State. N. Y. State Mus. Bul. 15, p. 555-56

EMERY

Conditions in the emery trade during the last year or two have encouraged the further development of the local supplies, and the output of the mines in the Peekskill district has assumed increased proportions, representing an important share of the emery available for consumption in this country.

Aside from New York State, Massachusetts and Virginia contain emery deposits that possess, or have possessed commercial value. The deposits at Chester, Mass., once supplied considerable quantities, but have been inoperative for some time and may not enter the market again. Virginia has contributed smaller quantities from an occurrence near Whittle Station, Pittsylvania county, where, it is reported, operations were under way last year. The Peekskill deposits have been worked continuously for the last 20 years and were operated in a desultory manner for an additional period of several years. Altogether they have yielded probably about 70,000 tons, of which amount over one-half has been taken out in the last three years.

The incentive for the recent growth of mining in the Peekskill district is to be found in the practical elimination of foreign emery

ores in the American markets. Ordinarily the home requirements are supplied mainly by importations of Grecian and Turkish emery, and the small amounts mined here are employed in admixture with the foreign ore which has come to be recognized as standard. The imports in normal times from Turkey and Greece have averaged about 15,000 long tons crude rock, worth from \$15-\$20 a ton. In 1916 they dropped to 7511 tons (\$102,459) and in 1917 to 650 tons (\$8875).

The output of the Peekskill district, for the years for which statistics are available, has been as follows:

Production of emery in New York

YEAR	SHORT TONS	VALUE
1904.....	1 148	\$17 220
1905.....	1 475	12 452
1906.....	1 307	13 870
1907.....	1 223	13 057
1908.....	690	8 860
1909.....	892	10 780
1910.....	978	11 736
1911.....	769	8 810
1912.....	589	6 479
1913.....	611	7 332
1914.....	63	9 105
1915.....	3 895	42 591
1916.....	15 282	123 901
1917.....	15 941	170 223
1918.....	8 183	61 660

It will be seen that the output for the years 1916 and 1917 measured up practically to the quotas formerly derived from abroad.

Occurrence. The Peekskill emery comes from the area of igneous rocks southeast of that city, that collectively are known as the Cortlandt series. They include a variety of types, mainly of basic nature, such as diorite, gabbro, norite, peridotite and pyroxenite and altogether form a compact mass some 7 miles in east and west extent by 5 miles north and south. The well-known Mohegan granite lies on the northeast border and may represent an offshoot of the same parent magma, as has been suggested by C. P. Berkey.¹ The geology and petrographic features of the area have been described in much detail by J. D. Dana, G. H. Williams and more

¹Science, v. 28, 1908, p. 575.

recently by G. Sherburne Rogers, the latter of whom also has given much information about the emery itself (see list of references at the end).

The emery occurs as bands and irregular bodies within the igneous area and seems to be distributed without rule, though it rather favors the border zone than the interior of the mass. Most of the emery has been mined in the eastern part of the area, from the region northeast of Pleasantside and farther south near Dickerson pond and Salt hill. The farms of I. McCoy, J. H. Buckbee and Oscar Dalton contain some of the larger bodies hitherto uncovered. The ore is usually mined by open cutting and the work is carried on mostly by hand. No deep mining by shafts has been undertaken and there is very little mechanical installation of any kind in the district. The ore as mined is roughly sorted according to its appearance and probable corundum content and hauled by truck to Peekskill for shipment.

Character. There is a great variation in the character of the emery, as appears from microscopic examination of samples and from results of chemical analysis. Rogers, who has made the most careful study of the ores, found that corundum constituted around 50 per cent of the mass as maximum. The best ores contain little else than corundum and magnetite, which Rogers classes as "pure" emery. Spinel emery contains as additional ingredient to corundum and magnetite a green spinel identified as pleonaste. Feldspathic emery resembles the latter but contains plagioclase which may constitute one-third or one-half of the rock. In conjunction with the feldspathic emery occurs a quartz variety which Rogers terms emery schist and which carried 50 per cent or so of silica which in the other grades normally is limited to a few per cent. Sillimanite is a conspicuous ingredient of some of the ores, occurring in long bladed crystals that are really distinguishable in the hand specimens. It is a contact metamorphic mineral, no doubt resulting from inclusions of schist in the igneous rocks. The area is bordered mainly by Manhattan schist, and there are fragments of the latter that have been entangled and completely surrounded by the magma on its way toward the surface.

It is from the inmelting of the aluminous-ferruginous schist that Rogers explains the origin of the emery ores. Through this action the magma became supersaturated with respect to these ingredients and consequently they separated out mainly as oxides. Another explanation possibly applicable is that the emery ores are segregations of the igneous magma, without any material contribution

from outside, just as the titaniferous iron ores (ilmenite-magnetite mixtures) are believed to have originated in the gabbros and anorthosites. A small percentage of ilmenite is present in the emery.

References

- Magnus, Harry C. Abrasives of New York State. N. Y. State Geol. 23d Ann. Rep't, 1904
- Nevius, J. N. Emery Mines of Westchester County. N. Y. State Mus. 53d Ann. Rep't, 1901
- Rogers, G. Sherburne. Geology of the Cortlandt Series and its Emery Deposits. N. Y. Acad. Sci. Annals 21, 1911, p. 11-86

FELDSPAR

Feldspar includes several mineral species, of which the useful kinds are orthoclase, microcline and albite. Orthoclase and microcline have the same chemical composition, but differ in crystal properties; they are silicates of alumina and potash containing in pure state 64.7 per cent silica, 18.4 per cent alumina and 16.8 per cent potash. Albite is the soda variety with 68.7 per cent silica, 19.5 per cent alumina and 11.8 per cent soda. Intergrowths of soda and potash feldspar are found which give practically all gradation in composition from the one extreme to the other; they are called perthite.

The sources of feldspar for commercial purposes are so-called pegmatites, those coarsely textured rocks that occur in dikes and small bosses as an accompaniment of deep-seated intrusions. Granite pegmatite supplies most of the product and is a mixture of potash feldspar, quartz and mica; it differs from ordinary granite in the size and more irregular distribution of the minerals. If the intergrowth is only moderately coarse and the crystals average not more than four or five inches in diameter, too much labor will be required in cobbing and such deposits have value only in connection with crushing plants for the preparation of material for artificial stone, roofing gravel etc. In the coarser phases the quartz and mica may be elements of value as well as the feldspar.

Pegmatites in New York State are limited in occurrence to the two areas of old crystalline rocks represented by the Adirondacks and southeastern Highlands. They occur in the vicinity of the larger granite intrusions but workable bodies are more often found on the border of such intrusions and within the old country gneisses and schists than in the midst of the granites themselves. They also occur in localities where ordinary granites do not outcrop,

but in this case they may be offshoots of some buried mass that were able to reach the surface on account of their more fluid condition.

The Adirondack region is well supplied with pegmatites but they are by no means equally distributed. The great anorthosite that spreads over the eastern central part mainly within Essex county holds no occurrences of granite pegmatite although it contains abundant occurrences of coarsely crystallized labradorite feldspar. The main sources of feldspar in this region are on the east, south and west sides of the Adirondacks where there are many very large intrusions of normal granite. The western Adirondacks, particularly the section included in Jefferson, St Lawrence and northern Lewis counties, is known to include numerous bathyliths and bosses of granite that cover a larger portion of the surface than in any other part; the granites are mainly coarse varieties, rich in quartz and containing many segregated masses of pegmatite. The conditions thus appear very favorable for the occurrence of extensive bodies of pegmatites in that section, but the remote and inaccessible nature of much of the area has rather discouraged exploration.

In the Highlands region and in Westchester county pegmatites are quite abundant, but only rarely reach workable dimensions. The principal bodies that have been exploited up to the present time occur near Bedford, Westchester county. In the central Highlands there is much pegmatite and coarse granite in evidence usually pinkish or grayish in color, but there are no developed quarries. The pegmatites occur in considerable bodies in the vicinity of some of the magnetite bodies.

Uses of feldspar. Feldspar finds varied employment. The principal outlet for high-grade potash spar is in the pottery industry particularly in the manufacture of porcelain, semiporcelain, china tablewares and porcelain sanitary wares and electrical supplies. For such uses it is essential that the feldspar should be free of iron and that it also be practically unmixed with any other minerals except quartz, the presence of which is allowable up to a certain extent. Anything more than a mere trace of iron serves to exclude the use of spar for making high-grade pottery. The proportion of feldspar used in the vitrified wares varies from 10 to 35 per cent; its use here is to bind together the quartz and kaolin, but it is also employed in the making of the glaze when this is required. Inasmuch as quartz is an essential ingredient of the pottery mix, the presence of quartz in the feldspar is not in itself objectionable, although some manufacturers of high-grade wares place a limit of five per cent upon the allowable free quartz.

Manufacturers of enamel ware, glazed brick and terra cotta consume considerable quantities of feldspar. In enamel ware the requirements are perhaps not so strict in regard to iron as in pottery manufacture, but the spar must be fairly free of quartz as the latter tends to raise the melting point. Among enamel ware and terra cotta manufactures a preference is occasionally shown for albite over potash feldspar owing to its lower fusing point. Little of this variety, however, is found in the New York pegmatites. Feldspar is used in the manufacture of opalescent glass. This requires a material of about the same quality as that for enamel ware, but may contain more quartz.

A large quantity of feldspar is employed as abrasive, especially in the form of scouring soaps and powders. For that purpose it is ground to an impalpable powder. It also finds use in the manufacture of abrasive wheels as a binder for the emery or carborundum with which the spar is mixed.

Unsorted pegmatite when crushed finds sale among makers of prepared roofing in which it is employed as a surface coating with tar or some bituminous binder.

The pegmatite is crushed to pea size or a little coarser and the feldspar by reason of its cleavage yields a flat surface that firmly adheres to the paper. Purity of the material is a subordinate factor and no effort is made usually to separate the different ingredients. The fine material resulting from the crushing is sold for use in concrete and grout and a small proportion of the coarser sizes finds a market as poultry grit. Crushed pegmatite has recently come into use in the preparation of artificial stone which is made to imitate granite and is cast in almost any form so as to require little or no tool dressing.

Production. The production of feldspar in New York State during the past few years has averaged between 10,000 and 15,000 short tons, inclusive of crude and ground feldspar and crushed unsorted pegmatite. The following table covers the period 1904-18 in which statistics have been collected by this office. The figures as given comprise a few thousand tons each year of quartz obtained in connection with the production of feldspar at the Kinkel quarries in Westchester county.

Production of feldspar and quartz

YEAR	SHORT TONS	VALUE	YEAR	SHORT TONS	VALUE
1904.....	9 747	\$28 463	1912	28 584	\$115 419
1905.....	19 040	48 500	1913	25 680	113 765
1906.....	15 292	44 350	1914	23 751	117 390
1907.....	9 770	36 230	1915	22 196	93 152
1908.....	16 413	68 148	1916	20 379	115 311
1909.....	16 111	52 444	1917	14 271	65 638
1910.....	18 012	64 503	1918	12 998	73 230
1911.....	21 802	75 719	.....	.....	.....

PRINCIPAL FELDSPAR OCCURRENCES

Crown Point. One of the more important pegmatite deposits now quarried is owned by the Crown Point Spar Co.; it is on Breeds hill south of Crown Point village and a mile or so back from the shore of Lake Champlain and 500 feet above it. The body is a boss rather than a dike, having an oval or rounded outcrop, with a longer diameter that runs northeast-southwest. Its full dimensions have not been revealed but it measures several hundred feet long and at least 300 feet in width. Feldspar occurs in two sorts, a pink potash variety and a greenish soda-bearing feldspar. It occurs in individuals up to 6 or 8 inches in diameter, but is more or less intermixed with quartz which is evenly distributed rather than segregated in large masses. Besides these minerals small amounts of biotite and occasional crystals of titanite, magnetite, zircon, tourmaline, pyrite, chalcopyrite and allanite are present. The pegmatite is now mainly crushed without sorting for use in making artificial stone, prepared roofing, etc.; formerly some pottery spar was sorted and ground separately. A biotite product may also be recovered. The crushed pegmatite is graded in six sizes, ranging from $2\frac{1}{2}$ mesh to very fine sand. The mill is situated at the base of the hill on the Delaware and Hudson railroad, and the rock is conveyed from the quarry by an overhead tramway.

Eight miles back of Crown Point on the road to Towner pond and three-fourths of a mile directly south of the latter, at an elevation of 1100 feet or more, is the Roe spar-bed actively worked 15 years ago as a source of pottery material. It is notable for the large size of the crystals which attain a cross section of 3 feet or more and are well segregated, so that a product low in quartz can readily be secured. Both potash and soda varieties are present, in about

equal proportions. Quartz is very subordinate and practically absent over considerable areas. There is little of graphic intergrowth. Of the iron-bearing silicates, biotite and black tourmaline are fairly common, but they are mostly localized in bunches and bands. The present quarry face is 75 feet wide and 50 feet high; it would appear that the body is a lens or stock having a northeasterly trend, but the outlines are not well-defined and the continuity of the pegmatite to northeast is uncertain as a grayish gneiss intervenes on the line of strike at no great distance from the face. There is however a large supply of material still obtainable. The main drawback to operations appear to be the remote situation which entails a long haul over a rugged country. The occurrence is on the property of H. W. Willcox of Crown Point.

Pegmatite apparently in a large mass outcrops on the road leading west from the south end of Penfield pond about due south of the preceding locality. It was noted by the writer several years ago but was not examined with reference to the quality of the materials. There are many occurrences in this section, notably in vicinity of Crane pond.

Ticonderoga. About 2 miles west of Ticonderoga at the eastern border of the Adirondack Precambrian area is a large pegmatite deposit that has been quarried extensively by the Barrett Manufacturing Co., principally for roofing material. The occurrence is similar to that at Crown Point, consisting of a lens of pegmatite with a longer axis running northeast, in Grenville gneisses, and the feldspar and quartz rather evenly distributed so as to be separable only with difficulty. The individual crystals measure 6 to 8 inches as a maximum. The principal dark mineral is biotite. Accessory tourmaline, garnet and iron sulphides are present. A mill equipped with crushers, rolls and screens is located at the quarry. The property has been idle during the last 2 or 3 years.

Fort Ann. A pegmatite body $2\frac{1}{2}$ miles northwest of this place has yielded both pottery spar and quartz. A small mill for grinding quartz was operated at Fort Ann some 30 years ago, and the material was quarried at different places in the vicinity and near Whitehall and Port Henry. The pegmatite quarry was last worked by Dominick Ashley, a few years since. It is a lens about 75 feet wide in the middle and two or three times as long, outcropping at the base of a gneiss ridge of which the summit part is known as Putnam mountain. The wall rock is a biotite variety of gneiss that may be classed as Grenville. The quartz and feldspar masses reach good size — 2 or 3 feet across — but there is considerable graphic

intergrowth of the two. Most of the feldspar has a grayish color and belongs to the microcline variety. Alteration and softening have taken place, with the formation of kaolin and sericite and small amounts of serpentine. The quarry pit is 125 feet long and 30 to 40 feet deep.

Chestertown. A muscovite pegmatite, in which the mica is abundant and of large size, is found 3 miles south of Chestertown on the north side of a high ridge $1\frac{1}{2}$ miles east of the Warrensburg road. It has been worked on a small scale for the mica, principally in two pits of which the larger is south of and higher up the ridge than the other and measures 50 feet long by 15 feet wide. The full extent of the body is not revealed.

Edinburg. Pottery spar has been obtained from a quarry on the farm of Adelbert Gordon, 2 miles north of Batchellerville, town of Edinburg, Saratoga county. The pegmatite outcrops at the base of a ridge which forms the steep eastern slope of the Sacandaga river valley, one-fourth of a mile east of the Day road. It has been worked in two pits. The minerals occur in coarse crystals, the feldspars attaining a length of fully 3 feet, but there is considerable graphic intergrowth. Most of the feldspar is a gray microcline, with subordinate amounts of a white variety which is probably albite. Muscovite is abundant in certain parts; it forms books and columnar crystals that measure a foot or more in diameter and from 1 to 10 inches thick, usually showing inclusions of iron oxides. Beryl is a common accessory constituent and attains unusual dimensions. The feldspar is of excellent quality. The main impediment to commercial operations is the long haulage; the nearest railroad point is Northville, some 8 miles distant over a rather difficult road. The Claspka Mining Co. opened the quarries in 1906.

Corinth. An extensive body of medium-grained pegmatite exists about 3 miles southwest of Corinth station on the Adirondack branch of the Delaware & Hudson Railroad. It has a width of 60 feet with a vertical range of 130 feet in the outcrop; it can be traced for 2000 feet along the trend but not continuously. The feldspar and quartz are too intimately intergrown for the mining of a high percentage of high-grade pottery material, although the former is mostly a potash variety. There is more or less biotite present. The occurrence is well adapted for making crushed pegmatite.

Mayfield. On the farm of Richard Tyrell, 3 miles west of Cranberry creek, town of Mayfield, Fulton county, is a deposit once worked for pottery spar. The quarry has a face 50 to 60 feet wide

and over 50 feet high and shows a coarse pegmatite, with white and red feldspars in masses 3 or 4 feet across. The white variety which appears to be albite is predominant; this is one of the few occurrences in which the soda spar is in excess over the potash variety, the latter being usually much the more common. The iron-bearing minerals are biotite and tourmaline. The quarry offers favorable conditions for the extraction of soda spar which is in considerable demand for producing enamels and glazes on wares that are fired at relatively low temperatures.

Undeveloped pegmatite bodies are found at several places in this vicinity.

De Kalb. In the town of De Kalb, St Lawrence county, on the Rowland farm along the highway from Bigelow to East De Kalb, is an occurrence of pegmatite that is made up almost entirely of feldspar and quartz, no dark minerals appearing in the outcrop. The feldspar is perthite, or an intergrowth of the potash and soda varieties in proportion of two or three parts of the former to one of the latter. The quartz is abundant, but by sorting much of the spar could probably be shipped as first grade. Individual crystals measure up to 3 feet long. The absence of iron silicates is noticeable and adds to the value of the occurrence for quarry purposes. The property has recently come under development, and shipments of pottery spar have been made during the past two years to Trenton, N. J.

Fine. Several deposits of pegmatite outcrop on the Fred Scott farm, 4 miles north of Oswegatchie, in the town of Fine, St Lawrence county. The feldspar is seldom free of admixture with other silicates. The occurrences are of interest mainly in connection with the well crystallized minerals to be found in them, the different species including pyroxene, hornblende, titanite, fluorite, pyrite and chalcopyrite. There is an abundance of pegmatite in this and the adjoining town of Fowler where a coarse granite outcrops in force, and doubtless some may be found that has economic character.

Kushaqua. About 4 miles from this place, in Franklin county, on the slope of Sable mountain is a pegmatite deposit that is reported to be very large. Samples show that the principal feldspar is microcline of reddish color and somewhat stained by iron. It occurs in rough masses rather than crystals and is admixed usually with other silicates — hornblende, biotite and tourmaline. The body has been prospected but not actively worked. The occurrence is too remote to merit much attention at present, particularly as the run of spar is hardly of first quality.

Bedford. The largest shippers of feldspar for pottery and other purposes in the State have been the quarries in Bedford township, Westchester county. The Kinkel quarries, on the hill southwest of Bedford village, are among the largest of their kind and have been actively worked for many years. They include several large pits in a pegmatite mass or boss whose outlines and extent have not yet been fully revealed. A notable feature is the coarse crystallization of the component minerals which in the case of quartz and feldspar attain unusual sizes. There is some graphic intergrowth of the two, but as a rule they are well segregated and both feldspar and quartz products are obtained. The feldspar includes microcline which is sold for pottery use and albite of which there are two grades according to the amount of admixed quartz, the higher grade finding use for enamelling and the more siliceous quality for glass. The quartz by itself is used in wood fillers and silica paints. Beryl, tourmaline and several rare uranium minerals are found here. Muscovite occurs in large sheets but is badly fractured and not suitable for cutting.

The Bedford Feldspar Co., a few years ago, opened a pit a few hundred feet north of the Kinkel quarries on the extension of the same deposit. The material is of the same character though containing less quartz than parts of the older quarries. The company ships its product in ground form for tile, enamel and glass manufacture.

The Bullock and Hobbey quarries are in the same section of Westchester county, but about 2 miles south of the former locality. The Bullock is west of the Hobbey and like the latter is based on a dike with a northeasterly trend. The pegmatite shows a high degree of mineral segregation, with little intergrowth of the quartz and feldspar, and the product largely is no. 1 grade, of which microcline constitutes two-thirds and albite one-third approximately of the total. The quarry face is 30 feet wide. At the Hobbey quarry the body is considerably larger, and the quarry opening is fully 100 feet wide. The feldspar here is likewise well segregated; individual masses 10 feet across are found.

References

- Bastin, E. S. Economic Geology of the Feldspar Deposits of the United States. U. S. Geol. Sur. Bul. 420, 1910
Emmons, Ebenezer. Porcelain, Clay and Feldspar. Geol. Rep't of the 2d Dist. (for 1838) 1839, p. 203-12
Newland, D. H. Quarry Materials of New York. N. Y. State Mus. Bul. 181, 1916, p. 154-175
Ries, H. Clays of New York, Their Properties and Uses. N. Y. State Mus. Bul. 35, 1900, p. 841-43

FLUORITE

There is no active mining of fluorite at present anywhere in the State, although it occurs in one or two places in considerable and possibly economic quantity. The mineral, the fluoride of calcium (CaF_2), has several important uses. The main purpose it subserves is as a flux, being much more active chemically than the other calcium compounds. Perhaps the largest single consumer is the open-hearth steel industry, but it is also employed to some extent in the shaft furnace and in the refining of certain base metals. The reduction of aluminum from the oxide is carried out in an electric furnace in a bath of fluorides, of which fluorite supplies the essential element. The manufacture of opalescent glass, enameled ware and hydro-fluoric acid calls for further quantities. A very limited but important use is in optics which requires clear transparent crystals of the mineral.

Fluorite occurs in association with certain magnetite deposits of the Adirondacks. It was found by the writer some years since in the examination of the Palmer Hill deposits as a component of the wall rock in contact with the ore and to some extent as a gangue of the latter. The main body of fluorite rock is to be seen in the hanging wall of the Big pit where it is traceable for 150 feet or more and contains from a few per cent up to 50 per cent of the mineral. The rock resembles the ordinary country rock in appearance, having a fine, even-grained texture, not pegmatitic, and the fluorite would readily be confused with quartz at first sight. The grains, of a fraction of an inch in diameter, are intermixed with pink feldspar and magnetite, with varying amounts of quartz. By increase of magnetite the wall rock grades into the commercial magnetites. If mining is resumed at Palmer hill, as seems not unlikely in view of the resources still in existence there, the recovery of fluorite as a by-product in concentration of the magnetite would appear feasible.

In the Barton hill section of the Mineville district fluorite occurs as a minor ingredient of the magnetite ores in restricted areas. It can be seen in the roof and walls of the present tunnel in the vicinity of the old workings called the Lovers hole. Wherever it occurs the magnetite appears as brilliant lustrous grains and crystals, which readily separate under slight pressure. The presence of the fluorite seems to have aided the segregation and crystallization of the magnetite. No mention was made of the fluorite in the early accounts of mining on Barton hill and its presence seems to have been ignored; the ore, however, is said to have behaved peculiarly at times in the furnace, for which the powerful fluxing qualities of this ingredient may have been responsible.

Other occurrences of fluorite that have been noted are mostly small veins in limestones. Whitlock¹ mentions the following as of economic or mineralogic interest. At Macomb, St Lawrence county, a small vein in limestone yielded about 15 tons of finely crystallized fluorite of sea-green color. At Muscalonge lake, Jefferson county, a vein was worked on a considerable scale about 75 years ago. The locality is on the east shore of the lake about 4 miles northwest of Oxbow. Another vein is found on Vrooman's lake about 2 miles east of the latter locality. Other occurrences in this general region are at the lead mines of Rossie and Mineral Point, and in the towns of Hammond, Fine, Gouverneur, De Kalb and Theresa. Elsewhere fluorite has been noted as occurring at Lockport and Rochester in the Niagara limestone, at Fayetteville, Onondaga county, Lowville, Lewis county, and Johnsburg, Warren county.

The veins associated with limestones are the main sources of supply for fluorite in general, but those in New York are hardly substantial enough to warrant mining under existing conditions.

FULLER'S EARTH

This material was formerly obtained in New York but has not been reported among the mineral products for several years past. It occurs at a single locality, so far as known, and the deposits seem to be rather meager to be workable under existing conditions. The following account of the occurrence is quoted from the volume by Prof. H. Ries² on "The Clays of New York."

"In New York, deposits of fuller's earth occur at a locality known as McConnellsville, 12 miles north of Rome on the Rome, Watertown & Ogdensburg railroad. The deposit has been worked for several years by the New York Fuller's Earth Co., and is a fine-grained, dense, Quaternary clay in layers 2 to 8 inches thick, interbedded with layers of sand of equal thickness. The total thickness is about 15 feet, and there is a capping of about 4 feet of sand. To mine the earth, the overlying sand has to be stripped off and the layers of fuller's earth taken off one by one, and spread in the sun to dry, the racks being movable, so that they can be shoved under cover in stormy weather. Thus far this fuller's earth has been used only for cleansing woolen goods, and it has been shipped to several factories in New York and neighboring states. A second mine of

¹ N. Y. State Geologist 23d Ann. Rep't, 1903, p. 187-88.

² N. Y. State Mus. Bul. 35, 1900.

the same material has been opened on an adjoining farm by M. A. Penfield. The New York material has thus far not been used for clarifying purposes, and it is doubtful if the deposit from McConnellsville will prove to be suitable for this purpose."

Tests in the laboratory indicate that the earth has not a strong decolorizing action on mineral oils, as compared with some of the southern earths. The application of fuller's earth to oil refining has become of much more importance than of cleansing wool, so far as the actual consumption is concerned. Very little of the domestic material is now used for the latter purpose, and the requirements are mainly imported. Fuller's earth also finds a limited outlet in the manufacture of pigments, as a substitute for talc, and as a reagent for food analysis.

The properties of fuller's earth are much like those of ordinary clay. It usually lacks the plasticity of clay, is more adhesive when touched with the tongue, and also absorbs water until it crumbles and flows. Practical tests are necessary to establish the commercial value of any particular sample. Chemical analysis shows that the earths from different localities have a wide range of composition which is without much significance as to their valuable properties.

GARNET

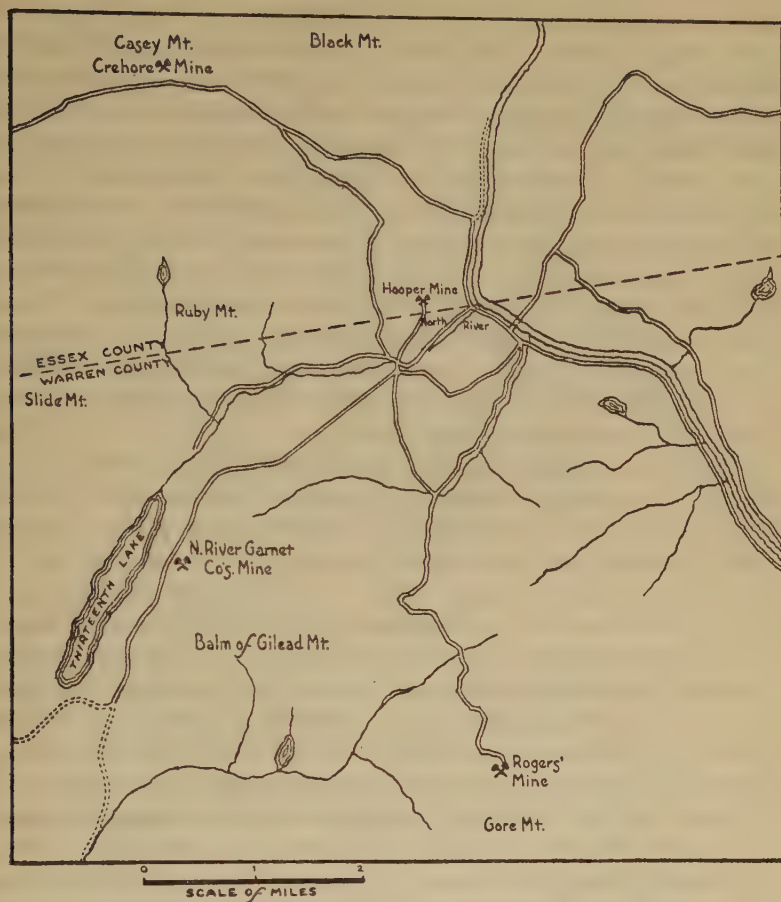
Conditions in the abrasive garnet industry have undergone no great changes recently as a result of the unusual trade developments. Some branches of the abrasive trade, however, experienced extensive readjustment owing to the curtailment or failure of supplies of the necessary raw materials which hitherto had been drawn more or less from foreign sources. The garnet business, however, being largely an American industry, was exempt from any disturbances of this character, and consumers were able to get plentiful supplies at prices a little above the average of previous years.

The use of garnet as an abrasive has obtained a firm foothold in this country, but strangely enough its value in that line has not been recognized to any extent abroad. The only foreign mines of any importance, so far as present yield is concerned, are those in Spain from which a few thousand tons of garnet have been obtained in recent years. This garnet finds little market in the European countries, but practically all of it is shipped to the United States for manufacture. Abrasive garnet has its own special functions and does not enter into competition with other abrasive materials to any extent, its employment being particularly in the woodworking and leather manufacturing industries.

Use. The utility of garnet as an abrasive depends upon the combination of several qualities, particularly hardness, toughness, cleavage or fracture, and the purity of the mineral. The varieties of garnet recognized by the mineralogist, of which there are a number that bear specific names, differ among themselves in respect to these qualities; this is true also to an important degree for the same kind of garnet in samples from separate occurrences. Almandite is the variety mostly used for abrasive work and ordinarily has a hardness on the mineralogists scale of 7 to 7.5. It is thus harder than quartz, but not so hard as corundum. From tests of the Adirondack almandite in the crystal form it would appear that the hardness may even exceed the degree indicated, as it has been found in certain instances to range from 7.5 to 8. Toughness has a direct bearing upon the service that may be expected from an abrasive, especially when used under pressure. A material may be hard but too brittle or too crumbly to stand up under heavy duty. The crystallized almandite has great strength and lasts well when used on abrasive machines.

Much of the Adirondack garnet has an imperfect cleavage, evident on crushing the crystal by the appearance of particles with one or more plane surfaces, but rarely with complete boundaries of that kind. Such parting, as it is called to distinguish it from cleavage proper, is an advantage if not so well developed that the mineral breaks down too easily; the planes supply sharp chisel-like cutting edges that make the garnet very effective on moderately soft materials.

The impurities that are commonly associated with garnet are mica, chlorite and hornblende. They reduce the strength of the garnet and also its cutting powers. Color is not a criterion of quality, but abrasive manufacturers express a preference for the true garnet red which shows up better on abrasive papers than the paler sorts. It is important that the crystals as they occur in the rock be large enough to stand the effects of the crushing and separating operations and still yield the necessary assortment of sizes. With small crystals the result of milling is to produce an excess of the fine sizes. A garnet rock with very small crystals would hardly afford a basis for commercial production, no matter how rich it might run in the mineral.



The North River garnet district

Occurrence. The active mines in the Adirondack region in the last two years included those worked by the North River Garnet Co. at Thirteenth lake, by H. H. Barton & Son Co. on Gore mountain near North Creek, and by the Warren County Garnet Mills near Wevertown, all in Warren county. As heretofore, the largest operations were carried on by the North River Garnet Co. who worked an open quarry in a great body of garnetiferous gneiss. The rock is perhaps a metamorphosed igneous rock allied to the syenite group, which is so abundant in the eastern and northern Adirondacks. The garnet occurs in the form of rounded grains and occasional crystal particles which range from a fraction of an inch to 4 or 5 inches in diameter. It has a dark red color and belongs to the almandite variety. The extraction of the garnet from the

matrix is performed by mechanical methods. After the rock is blasted in the quarry, it is loaded by means of a steam shovel into cars and is then transported to the mill, which is situated on the hillside below the quarry. The rock is there broken and crushed to a size which releases the garnet particles and then goes to jigs of special design. These effect a separation of the garnet and the accompanying gangue minerals of which hornblende and feldspar are the principal representatives. Inasmuch as the garnet and hornblende vary in specific gravity by less than one-half of a unit, careful work must be done to produce a garnet concentrate that is measurably free from foreign admixture, but the separation is performed successfully. The garnet from this locality has a darker color than that from the other mines now under operation and can be readily distinguished by that feature.

At the Gore mountain locality the garnetiferous material is confined to a long narrow band which possibly represents an altered dike of gabbro or an inclusion of Grenville gneiss in the country syenite, since it consists largely of hornblende and stands out prominently from the surrounding rock. The deposit is of much more limited extent than that at Thirteenth lake, but on the other hand contains a much higher percentage of garnet. This mineral occurs in rounded masses and aggregates, some of which attain great size, that is, 2 or 3 feet in diameter, and weights of a thousand pounds or more. The garnet masses are really crystals that have been subjected to powerful compressive strains which have resulted in its fracture into small angular particles, and when a mass is exposed in the quarry the garnet can be readily extracted by hand picking which is the method employed. The garnet from this locality, as well as that from Thirteenth lake, when crushed always yields one or more smooth surfaces which represent the parting planes characteristic of crystallized garnet.

In the occurrence near Wevertown the garnet is found in somewhat different association than that described. It consists of a light red garnet of granular habit intergrown or intermixed with green pyroxene, the two minerals together constituting the rock mass. In places the garnet may occur practically pure so as to form larger or smaller bodies by itself. When broken it rarely exhibits the parting, but shows a granular habit, the particles having irregular boundaries. A similar occurrence was worked for a while in northern Essex county near Keeseville, and there the garnet-pyroxene rock was clearly the result of contact metamorphic influences upon Grenville limestone. A small product has been obtained

from the Wevertown quarry in the last few years by the Warren County Garnet Mills.

The Crehore mine is the only other property in this section that has supplied any considerable production in recent years. It lies in the same district with the preceding occurrences but is in Essex county just north of the county line and about 5 miles northwest of North River on the Indian Lake road. The garnet is found in a band of hornblende gneiss which outcrops on the shoulder of Casey mountain just north of the highway. The exposure measures 40 feet or so in width and the band is said to be traceable for about 2000 feet. The garnet crystals measure 6 to 8 inches in maximum diameter. The matrix contains a large proportion of black hornblende and is somewhat like the Gore mountain garnet rock. The American Glue Co. has worked the mine at intervals for supplying some of its own requirements; up to the present time the product has been obtained by hand picking and cobbing. The company has plans under consideration for a mill to separate the garnet mechanically and with its facilities will be able to operate the property on a larger scale.

Another locality for garnet in this section is on Oven mountain, 4 miles south of North Creek, where some garnet was taken out 20 years or more ago. The occurrence is reported by W. J. Miller (see references at end of article) to resemble that on Gore mountain, consisting of a long narrow band of dark hornblende rock inclosed by syenitic gneiss. There has been a little work done on the Rexford property, about 1 mile south of North Creek.

Outside of the North Creek district the production of garnet has not been important although a number of occurrences have received more or less attention. The American Garnet Co. for a few years operated a deposit in northern Essex county, a few miles south of Keeseville on the Clinton county border. The garnet occurs in the form of rock in places almost free of admixture but usually containing a proportion of green pyroxene and belongs to the massive variety. It is inclosed within anorthosite, representing a band of Greenville limestone caught up and metamorphosed during the intrusion of the igneous rock. The product was sorted by hand and marketed in lump form, most of it being shipped abroad. The mining operations were suspended with the outbreak of the war.

About 3 miles north of Gouverneur, St Lawrence county, a body of garnet rock occurs that was worked for a time by Amasa Corbin. The garnet is in small grains not more than one-fourth of an inch in diameter as a rule, plentifully sprinkled through a green quartz-

feldspar gneiss that probably belongs to the Grenville series. The garnet has a granular habit and breaks with an irregular fracture. It would appear to be too fine to be available for general use, since after crushing and extraction the product is practically all of the smaller sizes.

Production. The shipments of garnet from the Adirondacks in 1917 were 4786 short tons, with a value of \$193,440. In 1918 the shipments amounted to 4126 short tons valued at \$232,661. The total of 5840 short tons (\$198,200) for 1916 set the record for the Adirondack mines.

Production of garnet in New York

YEAR	SHORT TONS	VALUE
1904.....	3 045	\$104 325
1905.....	2 700	94 500
1906.....	4 729	159 298
1907.....	5 709	174 800
1908.....	2 480	79 890
1909.....	3 802	119 190
1910.....	5 297	151 700
1911.....	4 285	121 759
1912.....	4 112	117 325
1913.....	4 665	145 445
1914.....	4 026	134 940
1915.....	3 900	134 064
1916.....	5 840	198 200
1917.....	4 786	193 440
1918.....	4 126	232 661

Considerable importations of garnet have been made in recent years for use by American abrasive manufacturers. In 1917 the imports were valued at \$14,456, tonnage not stated, and were all entered at the port of New York. In 1918 no imports of garnet were reported. The imported mineral comes from Spain where it is said to be obtained from river sands and not from rock. It has a fine grain and can not be substituted for all the purposes that the domestic garnet serves, although it has a limited use.

Garnet was first produced in the Adirondacks on a commercial basis about 1882. The earliest operations were on Gore mountain, in connection with the Rogers mine, the richest and in some respects the most remarkable of the deposits so far developed. The output in the first few years did not amount to more than a few hundred tons annually. By 1893 it had grown, however, to 1475 tons, as

is recorded by the *Mineral Industry* for that year. The next development of importance took place at the Hooper Brothers mine where the first use was made of mechanical separation for producing garnet concentrates. The mine and mill were located just west of North River in the town of Minerva, Essex county. The enterprise was abandoned after a time and mining started at the locality on Thirteenth lake, which is operated by the North River Garnet Co. with F. C. Hooper as president and manager.

References

- Hooper, F. C. The American Garnet Industry. The Mineral Industry, v. 6, 1897
Kemp, J. F. & Newland, D. H. N. Y. State Geol. 17th Ann. Rep't, p. 548-49, 1897
Magnus, H. C. Abrasives of New York State. N. Y. State Geol. 23d Ann. Rep't, 1904
Merrill, F. J. H. Mineral Resources of New York. N. Y. State Mus. Bul. 15, 1895
Miller, W. J. The Garnet Deposits of Warren county, New York. N. Y. State Mus. Bul. 164, p. 94-105, 1914

GRAPHITE

BY HAROLD L. ALLING

Graphite has been mined more or less extensively in the State since about the middle of the last century. The earliest operations probably were in connection with the Lead hill deposits near Ticonderoga which were mentioned in the reports of the First Survey published in 1842 and which in the next decade were under operation by an enterprise that eventually became the American Graphite Co. which is still in existence. The mines of Lead hill (also known as Chilson hill) were based on occurrences of crystalline graphite within contact zones produced by a coarse granite that were of rather sporadic character; later operations were transferred to the disseminated type of deposits in which graphite occurs evenly distributed through the mass of a quartzite or quartz schist, and these have since been the main source of supply.

General features of occurrence. The geology of the graphite deposits has been the subject of a careful investigation which is the basis of a report recently issued by this office (see list of references). The investigation has established the fact that the commercial deposits are found within the Grenville series of ancient metamorphosed sediments. The deposits are practically restricted to a stratum of quartzite or quartz schist that ranges from 3 to 30

feet in thickness. The bed and associated strata are traceable from near Lake Champlain west to Johnsburg in Warren county, a distance of 25 miles, and from the town of Hague, Essex county, south to Saratoga Springs, a distance of 40 miles. The graphitic rock does not occur as a continuous belt but in more or less isolated patches which represent the broken and eroded remnants of what were once probably continuous beds. The rock has been folded into anticlines and synclines, injected by various igneous rocks and faulted and dissected so that its present distribution is irregular.

In most of the deposits the graphite rock has the characteristics of a quartz schist. The average composition of the schist is about 60 per cent quartz, 20 per cent feldspar, 6 per cent graphite, 3 per cent pyrite and 3 per cent mica, with accessory minerals of smaller amounts. The foot wall of the bed is usually a feldspathic quartzite which in some places may contain more or less garnet, as instanced by the foot wall of the American mine at Graphite. Below this is hornblende schist or amphibolite. On top of the graphite rock and in some places interbedded with it as well is crystalline limestone; the limestone, however, is frequently absent in the graphite localities in the eastern part of the Adirondacks. Lying above the limestone is a thick bed of quartzite.

Mining. The graphite rock seldom occurs in such position that it can be worked to advantage by open cut methods. The deposits are thin as compared with their length and breadth and usually have a heavy cover. The seams are tilted horizontally at angles ranging from 5° to 10° up to verticality, and rarely follow a uniform dip for long distances underground but roll and pitch after the manner of folded beds. Mining consequently has to be carried on underground, although at the outset the exposed edges of the schists may be attacked by open cut methods if the rock is not too badly disintegrated by weathering which not infrequently is the condition owing to the presence of pyrite. Underground the beds are followed by inclines sunk on the foot wall, the angle of the incline conforming with the dip. On either side of the incline the rock is mined out in great chambers to the height of the bed. No timber is used and the pillars are usually placed wide apart as the roof is strong. Except for the variable dip of the beds which complicates the mining operations to some extent the conditions are favorable for economic working.

Separation. Various methods for the extraction of the graphite from the gangue have been practised in the Adirondacks but most of the mills have been designed for a wet process in which the main

dependence is put upon the buddle. The rock is broken by crushers and then further reduced by rolls or stamps until the graphite flake is in free form. The crushed material is then sent in launders to the buddle which is a cylindrical tank 16 or 18 feet in diameter and $3\frac{1}{2}$ or 4 feet deep. As the material is discharged into the buddle it undergoes gentle agitation so that the graphite flakes are carried to the outer edge owing to their buoyancy while the granular minerals collect within the interior zone. A second or even a third treatment may be required to make a fairly clean graphite product. After the separation the graphite is screened in order to eliminate more of the impurities and is then dried.

Within the last year the practice of the Adirondack mills has been completely changed by the substitution of oil flotation for the buddle. In the mill of the American Graphite Co. at Graphite, callow cells have been introduced and are reported to be giving good satisfaction. The flotation process, according to accounts, effects an increased saving of the graphite and reduces the amount of mica admixed with the product. This process has also been introduced in the plants of Hooper Bros. and of the Graphite Products Corporation.

Production. Interest in the production of flake graphite assumed unprecedented proportions last year. This was brought about by the scarcity of high-grade crystalline graphite in the domestic market owing to the curtailment of available shipping which interfered with the importation of Ceylon and Madagascar graphite and to embargoes placed upon the importations by the English and French governments for a period of 3 months. An abnormal demand for crucibles in the manufacture of alloys and alloy steels stimulated the market and brought about an increase of prices to nearly double the previous figures.

The New York mines did not register any important gain in the production of graphite in spite of the favorable conditions of the market, and the output for 1917 of 2,941,040 pounds valued at \$261,548 and in 1918 of 3,266,518 pounds valued at \$273,188 were only about the average quotas for the mines. The failure of the companies to respond to the stimulating conditions may be accounted for by the changes and improvements in progress in the mining and milling plants.

thicker of the two, is the one chiefly mined. The two beds are exposed on the other side of the fault while the Summer pit is located in the upper stratum. Considerable ore has been removed along the strike, but less along the dip as the line of the company's property is close by. The dip of the bed averages about 25° , but it frequently increases locally to 25° or even 45° . During the past year the American Graphite Company has not been operating at full capacity, being engaged in diamond drilling for exploratory purposes.

The Faxon property. The adjoining property held by William H. Faxon is still undeveloped, although more or less explored. The same geological conditions prevail on the Faxon property as on the former. Two main workable areas are available, one is the continuation of the main bed of the Dixon ore, the other is the Summer bed where it occurs on what is known as the Wheeler lot. The ore is frequently cut by minor faults. The supply of ore on this property is undoubtedly very large and the local conditions are favorable for mining.

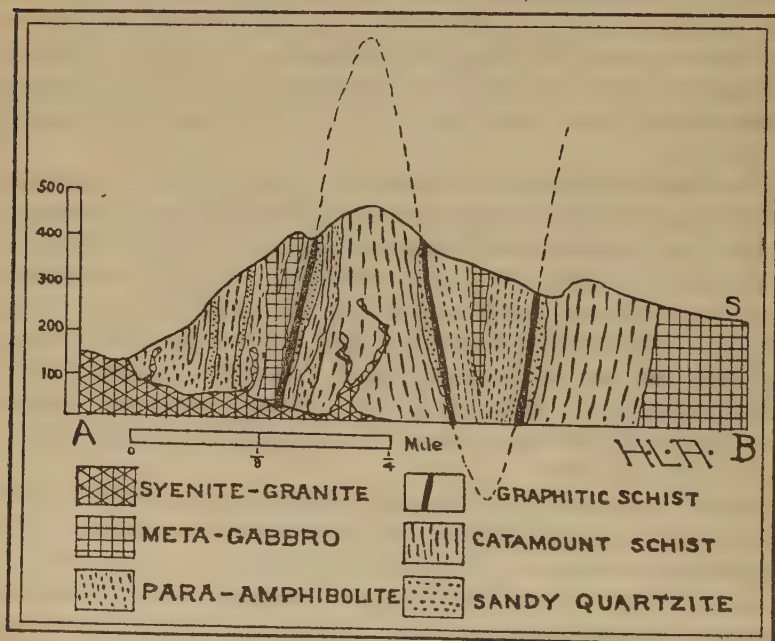
The Graphite Products Corporation. This company is operating a deposit 4 miles north of Saratoga where the graphite schist outcrops as two parallel strata due to repetition by step faulting. The rocks strike east and west and dip 32° to the south. The northern outcrop is the only one now being worked, the ore being quarried. There is a mass of metamorphosed gabbro and a diabase dike that interrupt the beds and cut across the graphite member. Concentration is accomplished by buddles, tables and screens. Hooper air jigs are employed in the refining process. The ore reserves of this property seem to be extensive.

Hooper Brothers. Another recently developed property is situated 2 miles west of South Bay of Lake Champlain and appears to be a promising enterprise. The bed of ore outcrops on the face of a steep cliff where both open-cut and underground methods are employed in extracting the schist. The ore is hoisted by cable cars into a mill located on top of the ridge where the usual method of concentration is practised, although considerable changes in equipment are being made.

Flake Graphite Co. A comparatively new-comer in the field is the Flake Graphite Co. The mine is situated 2 miles west of Porter Corners and 8 miles west-northwest of Saratoga. The geological conditions prevailing at this locality are very similar to those obtaining on the property of the Graphite Products Corporation. In fact it occurs in another portion of the same block of Grenville strata. Here isoclinal folding characterizes the locality. Mining

is confined to inclines and slopes extending 200 feet down the depth to the south on the face of the ridge. This company did not produce any graphite last year, but was engaged in development work. There is considerable ore in sight.

Pope Mills Graphite Co. This concern located near Pope Mills, St Lawrence county, reported a small production of both crystalline and amorphous graphite. The graphite bearing stratum here carries amounts ranging about 25 per cent, much of which is amorphous in character. Evidently the metamorphic agencies were less pronounced in the northwest Adirondacks in comparison with the eastern area.



Vertical section of the Bear Pond Mountain region, showing the isoclinal folding of the Bear Pond schist and associated rocks

Bly property. This property is situated in the township of Ticonderoga on the northern slopes of Bear Pond mountain and presents some rather promising features. The writer believes that the ore on this property is a stratum higher up in the geological scale than the graphite bed displayed at the other properties in the eastern Adirondacks. The Bly ore is a feldspar-quartz-biotite-graphite schist. The beds have been isoclinally folded so that the outcrop

follows a Z-shaped line on the map. The amount of graphite in the ore averages about $6\frac{1}{2}$ per cent.

References

- Alling, Harold L. The Adirondack Graphite Deposits, N. Y. State Mus. Bul. 199, 1918
 Bastin, E. S. Chapter on Graphite in Mineral Resources, U. S. Geol. Surv. 1908, v. 2
 Beck, Lewis C. Mineralogy of New York, 1842
 Emmons, Ebenezer. Geology of New York. Report on the 2d Dist., 1842
 Kemp, J. F. & Newland, D. H. Preliminary Report on the Geology of Washington, Warren and Parts of Essex and Hamilton Counties. N. Y. State Mus. Rep't 51, v. 2, 1899

GYPSUM

This industry has grown rapidly in recent years. For a long time gypsum was produced only for agricultural purposes, the rock being ground to a powder and sold under the name of land plaster as a soil amendment. The usual output of the local quarries and mills engaged in the business was around 30,000 tons a year, but showed little tendency toward expansion. In fact with the increased use of ground limestone and lime in agriculture, which has been promoted recently by a general propaganda of government and local agricultural organizations, the consumption of ground gypsum has fallen off in competition with the cheaper material, although it is not certain that the limestone fulfills entirely the function of gypsum as a beneficial agent.

The growth of the industry has come about through the introduction of calcined plaster manufacture in the local field, supplemented by the large demand for raw gypsum that has developed out of the portland cement business which has shown a remarkable gain in the last few years.

The first attempts to make commercial use of the local deposits are reported as having been undertaken in the period from 1810 to 1820 when small quarry operations were carried on in the town of Sullivan, Madison county, and in the town of Camillus, Onondaga county. This product was employed locally for agricultural purposes. With the building of the Erie canal a wider market was opened for the material and quarries were soon established at other localities, within the central and western parts of the Salina belt which contains the workable beds. Union Springs, Seneca Falls, Phelps, LeRoy and Wheatland are some of the places that were early identified with the industry.

In 1843, according to the geologists of the first survey, the output

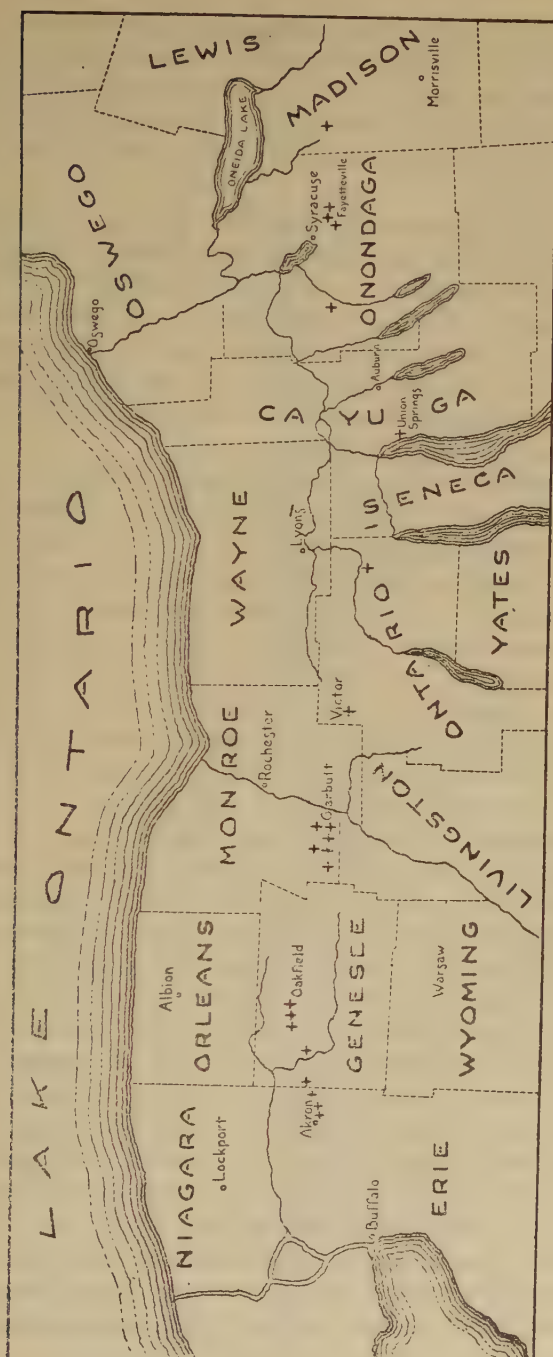
was about 33,000 short tons, which figure was rarely exceeded during the next 50 years. Practically the entire product was used in agriculture. The first definite impulse toward an enlargement of the industry came in 1893 when the application of gypsum to plaster manufacture was successfully inaugurated at Oakfield. The amount reported under that form for that year was only 75 tons, as compared with 33,781 tons sold in crude condition. In 1899 the quantity employed in calcined plaster exceeded that of all other uses combined. The trade in crude gypsum as a cement retarder began to assume importance about 1905 when 34,095 tons were reported as sold in lump form, nearly all of it doubtless going to portland cement makers. In the same year the calcined plaster output was 130,268 tons, and the production of agricultural plaster was 19,815 tons.

The present status of the industry is indicated by the following table for the years 1916, 1917 and 1918. It is to be noted that the figures for calcined plasters in the last item of the table represent the product obtained from gypsum quarried within the State and is exclusive of any materials made by calcination of imported gypsum. There are a number of mills which customarily import more or less of the crude rock, although in the last year or two importations have not been made as freely as heretofore owing to the high cost of shipment. Most of this imported gypsum has come from the Maritime Provinces and has been used in mills located along tide water, i. e. the lower Hudson and New York bay.

Production of gypsum in New York

MATERIAL	1916		1917		1918	
	SHORT TONS	VALUE	SHORT TONS	VALUE	SHORT TONS	VALUE
Total mine output.....	579 827	.....	606 268	.....	531 038	.....
Sold crude.....	188 077	\$273 322	218 094	\$400 836	179 968	\$442 087
Ground for land plaster.....	7 169	18 710	5 298	20 235	3 139	14 552
Wall plaster, etc.....	311 264	1 167 555	304 364	1 615 749	275 333	2 213 460
Total.....	.....	\$1 459 587	.....	\$2 036 820	.....	\$2 670 099

The mine output of 606,268 tons in 1917 set a new mark for this State which maintained itself well in the lead among the producers of gypsum and its products. The gain was brought about by increased shipments of crude rock, that is in the gypsum sold to



Map of the gypsum belt to show location of mines and quarries

portland cement mills; the product of calcined plasters and of land plaster each showed a slight decrease as compared with the returns for 1916. The 1918 output at the mines of 531,038 short tons is a decrease of 75,230 tons from the 1917 production, but with the higher prices obtained shows an increase in value of the products sold of \$633,279.

Uses. Recent experimental tests with gypsum in agriculture have revived interest in the use of land plaster, indicating that it has a positive fertilizing value for some crops, notably grains, grasses and legumes. Its principal function is as carrier of sulphur, which enters into the structure of many plants in proportions comparable to those of phosphorus, the basis of most prepared fertilizers. Gypsum also improves the mechanical condition of soils and effects certain beneficial chemical reactions.

Portland cement manufacture calls for about one-third of the mine product of the State. For this purpose the rock is crushed to small size, usually through one-half inch mesh. About two per cent is added to the clinker as it comes from the rotary kilns and is ground with it. Its function is to delay the set of the cement. The demand is for a high-grade gypsum, and sales are made on the basis of the sulphuric acid content.

The major portion of the mine product is calcined into stucco, usually in plants operated by the mining companies. The stucco is admixed with a small amount of retarder and some fiber like hair or shredded wood and becomes hard wall plaster. Such plasters are harder and attain their final set much quicker than lime plasters. A constantly increasing proportion of stucco is being converted into such materials as plaster board, wall board, blocks and tiles, the manufacture of which is one of the recent developments that seems to promise most for the future of the industry. Plaster board and wall board are sheets of stucco lined on either side with paper and designed to be applied directly to the studding, without the use of lath. Wall board requires no coat of plaster to give a finished appearance. Plaster board if applied to inside walls is given a single coat, but it is also used on the outside for sheathing and as lining in the place of lumber. Gypsum block and tile are made in a variety of sizes and shapes, taking the place of clay articles in fire-proof construction for floors, partitions and roofs.

Occurrence. The supply of gypsum is obtained from a single series of deposits which is confined to the Salina stage of the Silurian system. The main occurrence of the Salina strata is repre-

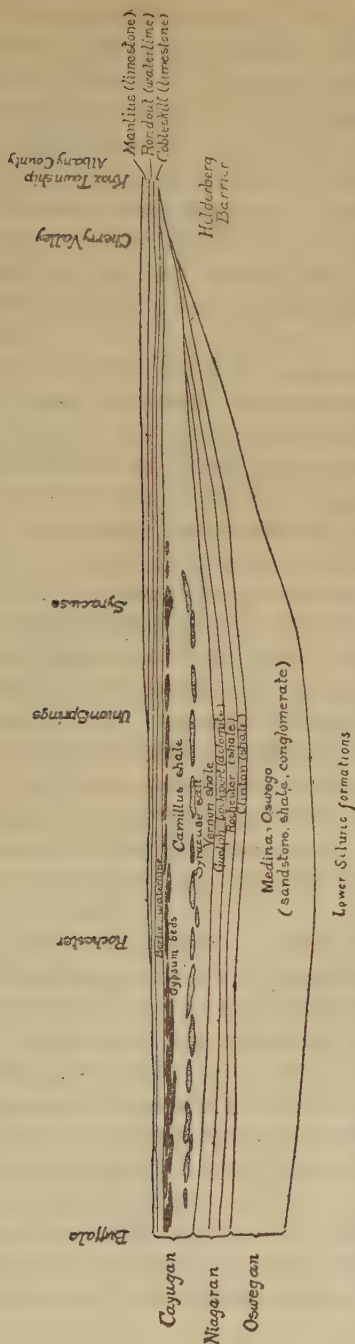


Diagram indicating relative position and linear extent of the Silurian strata in New York State between Erie and Albany counties

sented by a belt that stretches east and west from the town of Knox, Albany county, to the Niagara river at the western border whence it continues into the province of Ontario, Canada. The belt is thus about 250 miles long; in width it varies all the way from less than a mile to 20 miles wide. The maximum width, as well as thickness of the strata, is attained in central New York in Onondaga and Cayuga counties. The strata have a low dip (averaging about 50 feet to the mile) to the south, which carries them under the higher members of the Silurian and of the Devonian rocks that spread over the area lying between the Salina and the Pennsylvania state line.

The Salina strata consist of shales, limestone, rock salt, anhydrite and gypsum. The uppermost layers are usually argillaceous limestone, to which the name Bertie waterlime is given. The rock forms a capping for a large body of shale, with intercalations of limestone bands, known as the Camillus shale, usually drab in color. It is in this formation, and commonly within 100 feet or so of the top that the gypsum beds occur. The total thickness of the shale and gypsum probably reaches 300 feet in central New York. Below the Camillus lies the rock salt which has been traced from Madison county west to Erie county, and the red Vernon shales which are the thickest member of the Salina, attaining about 500 feet in the vicinity of Syracuse. The horizon of the salt can not be determined accurately with reference to the gypsum, since the beds do not extend to the outcrop and few of the drill records in the salt district make any mention of gypsum or the related mineral anhydrite. It appears probable, however, that the interval is a variable one and may range from 50 to 200 feet or more in different places.

The Camillus formation in western New York holds an important calcareous element, particularly in the upper 100 feet which is largely composed of thin-bedded magnesian limestones, scarcely different in appearance from the Bertie layers above. The gypsum is associated with these limestones in seams arranged parallel with the bedding. A foot or two of gypseous shale, so-called "ashes," usually accompanies the deposits, most commonly lying above in immediate contact with the gypsum. It weathers rapidly and consequently makes a poor roof. It looks more like a residual product of the limestone beds than a true shale and seems to diminish or disappear in the deeper zone. A section of the gypsum beds, showing the characteristic order, is here given from the Akron district.

	<i>Feet</i>	<i>Inches</i>
Earth.....	18	.....
Limestone.....	3	4
Mud seams.....	3	.....
Limestone.....	3	8
Mud seams (water bearing).....	4	.....
Limestone.....	21	.....
Gypseous shale (ashes).....		4
Gypsum.....	1	.....
Limestone.....	4	.....
Ashes.....		8
Gypsum.....	4	.....

Gypsum favors the superficial zone where water circulates readily and most of the mines consequently are wet. As the beds deepen toward the south on the dip and become covered by the Devonian formations, the gypsum gives way to anhydrite, the material commonly encountered in all deep borings and in the salt shafts and wells several miles south of the Salina outcrop. The change from gypsum with its content of 20 per cent or so of combined water to the water-free and commercially worthless anhydrite takes place quite abruptly, an increase of 10 feet of depth often marking the complete passage from the one to the other. In mining, it is of course useless to follow the seam beyond the limit marked by the appearance of anhydrite in quantity.

As a guide to the occurrence of gypsum in the field the outcrop of the cherty beds of the Onondaga serves best, since it is usually indicated by a sharp break in the topography or by a line of cliffs, whereas the softer Camillus shales that lie below rarely are indicated by topographic changes. The outcrop of the latter is just north of that of the cherty beds and usually occupies a strip of low ground a mile or more in width in which there are few exposures.

The outcrop of the gypsum does not lie at a constant level, but ranges through an interval of 300 feet or so, between the approximate limits of 750 feet which marks the elevation above sea level of the beds at Oakfield and 400 feet which represents the low point along the belt found at Seneca Falls, Seneca county. The variation is very gradual, scarcely perceptible within narrow limits, but appears when the line of contact is traced, on the contour maps. It is an inheritance from an early period, possibly dating back to the Appalachian uplift and representing the last traces of differential movement to the north of the main axis.

Nature of deposits. The deposits consist of compact gypsum usually of homogeneous appearance, which, however, varies considerably from place to place in regard to purity. This is the rock gypsum which forms the basis of the calcined plaster industry, as

well as of the production of material used in portland cement. Microscopically it shows a crystalline texture, with interlacing fibers and blades of gypsum that inclose more or less of clayey matter and carbonates in the interstices. The proportion of the sulphate to the impurities depends more or less upon local conditions, but in a broad way it can be stated that there is a progressive increase in the percentage of gypsum substance as the deposits are followed from central New York into the western section. In Madison, Onondaga and Cayuga counties the rock carries from 65 to 80 per cent gypsum. In Monroe county it averages probably around the upper of these limits. In Genesee and Erie counties on the west end analyses show 90 per cent and up to 96 per cent of hydrated calcium sulphate.

Analyses of New York gypsum

	1	2	3	4	5	6
SiO ₂	.51	1.03	.40	2.93	8.31	4.00
Al ₂ O ₃	1.19	.41	2.97	1.92	4.53	1.74
Fe ₂ O ₃	.79	1.27	.77	1.10	1.34	1.11
CaO.....	30.62	30.74	30.76	26.27	21.50	29.36
MgO.....	1.20	2.01	1.53	8.29	7.20	2.81
SO ₃	43.59	42.39	43.78	33.83	30.47	35.79
CO ₂	1.02	2.20	2.80	11.02	9.50	6.38
H ₂ O.....	20.52	18.19	17.53	14.87	14.53	17.93
Gypsum.....	93.74	91.27	94.26	72.84	65.49	77.06

1 Akron, Erie county, 2 Oakfield, Genesee county, 3 Oakfield, Genesee county, 4 Garbutt, Monroe county, 5 Lyndon, Onondaga county, 7 Lyndon, Onondaga county. All analyses by George E. Willcomb.

The thickness of the beds probably may be said to stand in inverse relation to their quality. The thickest are encountered in Onondaga and Cayuga counties—60 feet in the Severance quarry at Lyndon east of Syracuse and 30 feet at the Union Springs locality in unbroken mass from top to bottom except for thin shale partings. In Monroe county two beds have been generally proved to occur where exploration has been undertaken—each from 5–8 feet thick separated by from 6 to 12 feet of hard limestone. In Genesee county there appears to be only a single workable bed which averages 4 to 6 feet. The same condition holds for the eastern part of Erie county. In the city of Buffalo a series of test holes drilled several years ago showed the existence of two 4 foot beds of white gypsum with about 20 feet of intervening shale in which a thinner seam of gypsum is inclosed.

It is quite apparent the deposits are not continuous beds in the broad sense, but rather are made up of a number of layers distributed



MAP OF THE WHEATLAND GYPSUM DISTRICT

List of Workings—(1) Abandoned adit, McVane farm; (2) mill; (4) mine, Empire Gypsum Co.; (3) mill; (9, 10) shafts, Garbutt Gypsum Co.; (5) mill; (6, 7, 8) mines, Lycoming Calcining Co.; (11) gypsum deposit, M. Rogers farm; (12) shaft and crusher, Monarch Plaster Co.; (13) adit; (14) mill; (15) shaft, Consolidated Wheatland Plaster Co.; (16, 17) abandoned workings.

along the outcrop so as to give a varying succession from place to place. Although they occur near the upper limits of the Salina, having the Bertie waterline as marker of the highest possible horizon, they may and do occupy different positions within the shale. Owing to the fact that the gypsum is rather soluble in ground waters and is also easily eroded, the outcrop is likely to be concealed; drilling is the most practical method of testing undeveloped ground.

Mining operations. The production of gypsum in recent years has been carried on in the following counties from east to west — Madison, Onondaga, Cayuga, Monroe, Genesee and Erie. Of these the first three produce rock suitable for grinding, but hardly adapted for calcined plasters when used alone. The cement mills of New York have employed the material from this section and some of the output in years past has been sold to calcining plants for incorporation with higher grade plaster made from rock obtained elsewhere. The output at present is small, and is mainly from the deposits around Jamesville and Fayetteville. At Union Springs extensive operations were carried on for a time, but the property is now closed. Owing to the thickness of the beds in this section open-cut quarry work is the usual method of extracting the gypsum.

In the town of Wheatland, Monroe county, the Empire Gypsum Co. and the Lycoming Calcining Co. operate extensive mines, as well as plants for the conversion of the output into stucco and other products. The workings are all underground, reached by drift openings from the outcrop of the gypsum beds along the depression of Allen creek, and are similar to the room-and-pillar method of coal mining. The rock is light gray or brown in color and contains numerous veinlets of fibrous gypsum, pure white. It averages 5 to 6 feet thick. The upper of the two seams only is worked. From the mines the broken gypsum is taken to the mills by tram and there in part calcined and in part crushed or ground for shipment to cement mills and for agricultural uses. The Ebsary Gypsum Co. also is active in this district having a mine near Wheatland Center and a mill for making stucco on the property, which adjoins the Buffalo, Rochester and Pittsburgh Railroad.

The section of the gypsum belt between Oakfield, Genesee county, and Akron, Erie county, a distance of 12 miles, has been the center of the principal developments in the last few years. The district is traversed east and west by the West Shore branch of the New York Central lines, affording convenient shipping facilities, while the beds are close to the surface and afford light-colored rock of

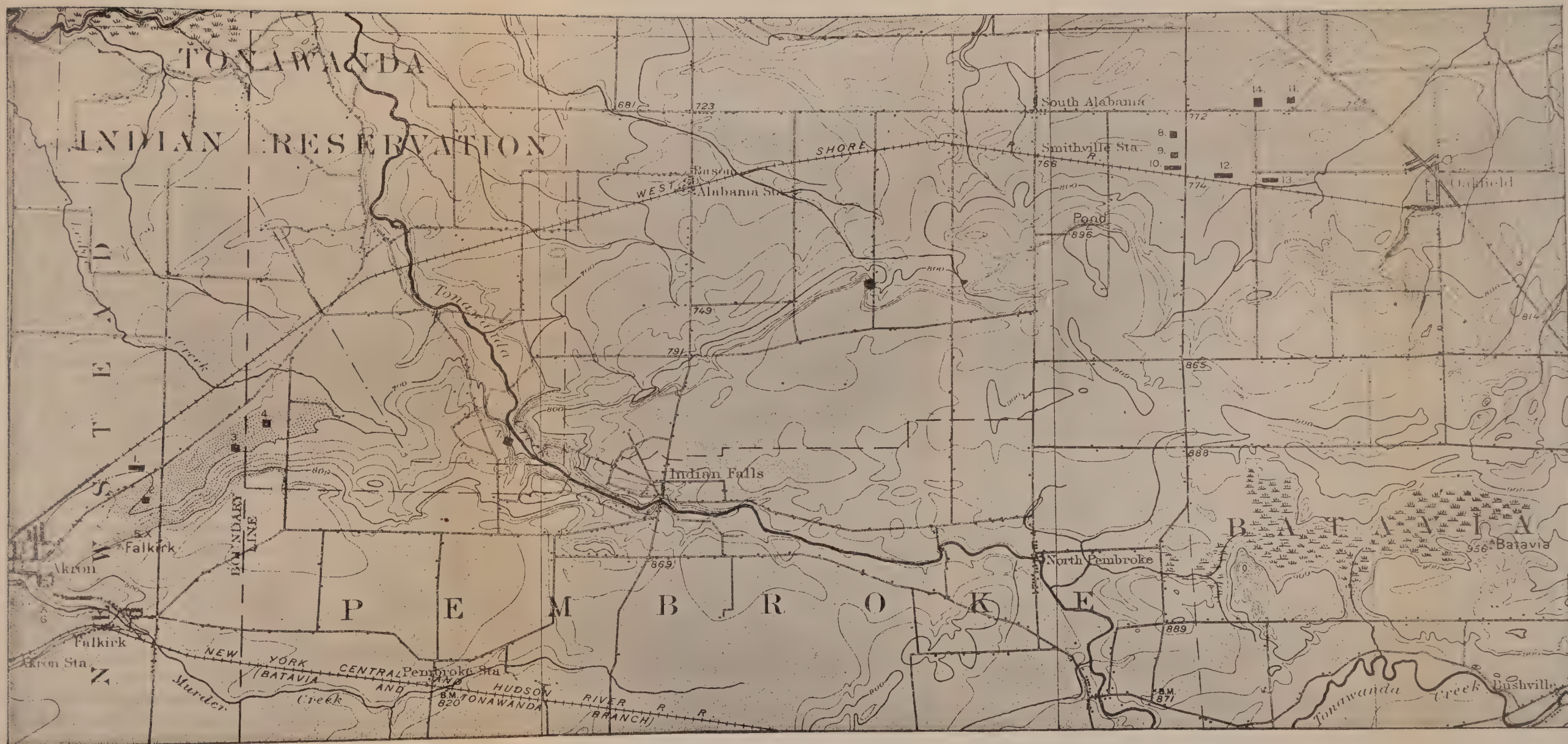
good grade. The mines are opened by vertical shafts, usually less than 100 feet deep, and are equipped and operated after approved modern methods. Extensive use is made of electricity for hoisting and lighting.

Just west of Oakfield are the mines and mills of the United States Gypsum Co., which entered the New York field about 1903 and whose enterprise gave the impulse to the recent rapid growth of the industry. The mines are the largest in the State and altogether embrace several hundred acres. The larger share of the output is calcined and sold in the form of stucco, wall plaster, board, blocks etc., but a considerable tonnage goes to cement mills. The company operates a separate plant for making building blocks and tile.

The Niagara Gypsum Co. works the gypsum bed to the west of the above mentioned property, its mine and mill being about 2 miles west of Oakfield, or $\frac{1}{2}$ mile east of South Alabama. The mill is equipped with rotary kilns for calcining the gypsum, whereas the usual practice is to employ vertical retorts or kettles. The advantage of the rotary kiln lies in its greater efficiency from continuous operation. The workable gypsum is present in a single bed 4 to 5 feet thick.

Between the latter property and that of the American Gypsum Co. near Akron is an interval of about 8 miles in which it is not unlikely that gypsum deposits of economic grade and size occur although no mining operations are being carried on at present. The American Gypsum Co. operates on an extensive scale, having a thoroughly equipped mine in which electric power is largely used, and a three-compartment shaft for hoisting the product to the surface. A crushing plant is located at the shaft. All the output is sold crude to cement mills and to calcining plants elsewhere. The bed underlying the property is about 4 feet thick and together with the continuation of the bed under the adjoining lands seems to be an attenuated lens which gradually thins down to the east and west. The gypsum is of excellent quality.

The American Cement Plaster Co. operates a mine in this area, having entered the district recently as successor of the Akron Gypsum Products Corporation; the property was first opened in 1908 by the Akron Gypsum Co. The mine is a mile northeast of Akron and is connected with a calcining plant nearby which utilizes most of the output. This is the last of the active mines in the belt to the west.



MAP OF THE OAKFIELD AND AKRON GYPSUM DISTRICTS

List of Workings — (1) mill; (2) shaft, Akron Gypsum Co.; (3, 4) shafts, American Gypsum Co.; (5, 6) test holes; (7) abandoned workings, Standard Plaster Co.; (8, 9) shafts; (10) mill, Niagara Gypsum Co.; (11, 14) shafts; (12, 13) mills, U. S. Gypsum Co. The proven gypsum territory near Akron is shown by dotted area.

References

- Luther, D. D. Economic Geology of Onondaga County. N. Y. State Mus. 49th Ann. Rep't, v. 2, 1898
- Merrill, F. J. H. Salt and Gypsum Industries of New York. N. Y. State Mus. Bul. 11, 1893
- Newland, D. H. & Leighton, H. Gypsum Deposits of New York. N. Y. State Mus. Bul. 143, 1910
- Parsons, A. L. Notes on the Gypsum Industry of New York. N. Y. State Geol. 23d Ann. Rep't, 1904

IRON ORE

Iron ores are first in the list of metallic minerals that are mined within the State, outranking all others in extent of distribution and industrial importance. They are distributed among several districts, each having more or less independent geologic features and characteristic ore types. The different kinds of ores that have been the object of mining operations include magnetite, magnetite-ilmenite mixtures, massive hematite, fossil and oölitic hematite, limonite, siderite and bog ores.

The beginnings of iron mining and manufacturing in New York trace back to the colonial period and took place in the southeastern section. The earliest record of iron making that seems to be well authenticated by contemporary evidence refers to an enterprise on Ancram creek, Columbia county, which from its location renders fairly certain that the local limonite ores were employed. In 1750 a limonite deposit near Millerton, Dutchess county, a part of the Salisbury district, was opened. The same year saw the start of mining in the Highlands magnetite district, with the development of the famous Sterling mines in southern Orange county, which have been under practically continuous operation, except for short intervals of inactivity, down to the present time. A furnace was erected on the Sterling property in 1751 and the iron made there during the Revolution played an important part in supplying the needs of the patriot army. The Forest of Dean mine, back of West Point, in the Highlands was opened about 1756.

The Adirondack magnetites began to be worked about 1800 as small forges were in operation in the Champlain valley in 1801.¹ The occurrence of ore in that region was known many years before that time, as it is indicated on the early maps during the French occupation of the Champlain valley.

The Clinton formation with its fossil and oölitic hematites came

¹ Most of the information about the early history of iron mining is from Swank, "History of the Manufacture of Iron in All Ages," Philadelphia, 1888.

under exploration at the opening of the nineteenth century; a lease for digging the ore is said to have been taken out in 1797.

Production. The record of the iron mining industry has been marked by wide fluctuations of activity and prosperity. It is not possible to trace the course of operations over the long period of years that has elapsed since the start of mining; only from 1890 have complete statistics of production been compiled that indicate the sequence of changes. This period, however, encompasses the most eventful part of the entire history, within which the iron trade of the country has been practically revolutionized by the improvements in metallurgical practice and by the development of important additional ore supplies, like those of the Mesabi range.

In the years from 1860 to 1890 New York played a very considerable role in the iron trade of the country. Forges and furnaces were operated in many parts of the Adirondacks, in southeastern New York and in the Clinton belt of the central and western sections, deriving the supplies of ore from the nearby deposits. Of special importance was the bloom iron, made in open forges with charcoal, which had a wide market. Soon after 1890 the industry began to decline from competition with the new fields in the middle west, and for several years it experienced a profound depression which brought mining almost to a standstill. About 1900 a recovery from these conditions was to be noted; metallurgical enterprises were reestablished, and mining was gradually resumed in the old centers. The perfection of the processes of milling iron ores, particularly of the method of magnetic separation as applied to magnetites, gave a stimulus to this revival of the industry. In the last year or two production has been larger than ever before.

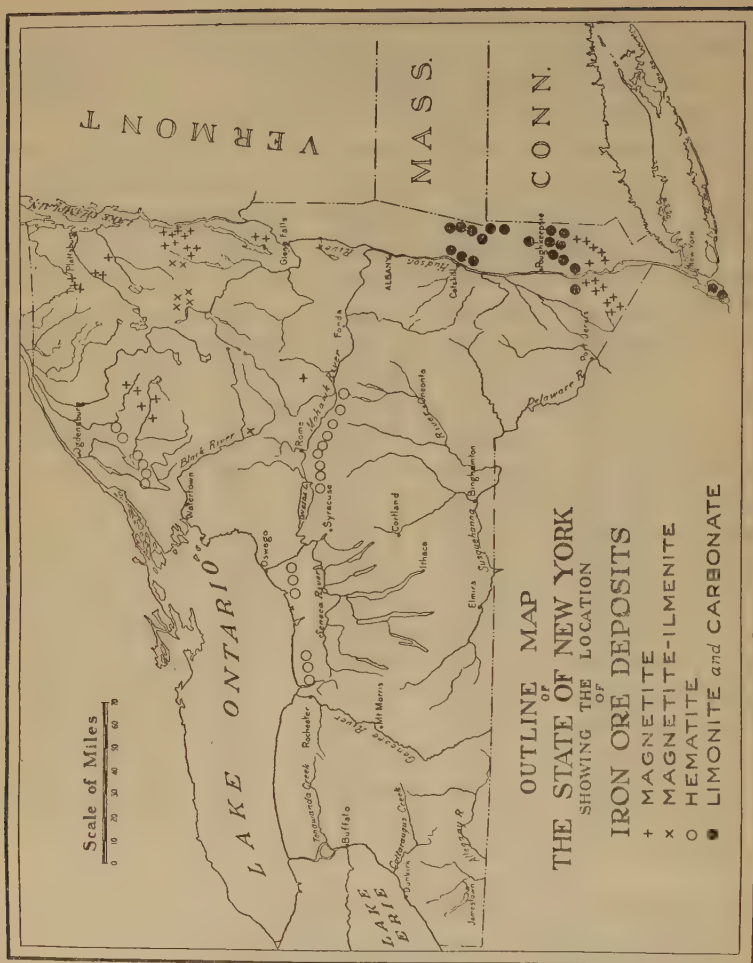
The future progress of the iron-mining industry will depend largely upon the utilization of the low-grade ores — those containing as low as 20 or 25 per cent iron in the crude state. There are immense resources of such ores, the total quantity not being subject to close estimate but is known to run up into the hundreds of millions of tons, many times the amount that has so far been mined. Some of the more important supplies are the magnetites of the Adirondacks and southeastern Highlands, the magnetite-ilmenite mixtures of Essex county, the limonite ores of Dutchess and Columbia counties, and the Clinton hematites of central and western New York.

Production of iron ore in New York State

YEAR	MAGNETITE LONG TONS	HEMATITE LONG TONS	LIMONITE LONG TONS	CARBON- ATE LONG TONS	TOTAL LONG TONS	TOTAL VALUE
1880....	927 052	180 207	154 868	Nil	1 262 127	\$3 654 872
1890....	945 071	196 035	30 968	81 319	1 253 393	.....
1891....	782 729	153 723	53 152	27 612	1 017 216	.....
1892....	648 564	124 800	53 694	64 041	891 099	2 379 267
1893....	440 693	15 890	35 592	41 947	534 122	1 222 934
1894....	.....	.....	.....	.....	242 759	.....
1895....	260 139	6 769	26 462	13 886	307 256	598 313
1896....	346 015	10 789	12 288	16 385	385 477	780 932
1897....	296 722	7 664	20 059	11 280	335 725	642 838
1898....	155 551	6 400	14 000	4 000	179 951	350 999
1899....	344 159	45 503	31 975	22 153	443 790	1 141 985
1900....	345 714	44 467	44 891	6 413	441 485	1 103 817
1901....	329 467	66 389	23 362	1 000	420 218	1 006 231
1902....	451 570	91 075	12 676	Nil	555 321	1 362 987
1903....	451 481	83 820	5 159	Nil	540 460	1 209 899
1904....	559 575	54 128	5 000	Nil	619 103	1 328 894
1905....	739 736	79 313	8 000	Nil	827 049	2 576 123
1906....	717 365	187 002	1 000	Nil	905 367	3 393 609
1907....	853 579	164 434	Nil	Nil	1 018 013	3 750 493
1908....	663 648	33 825	Nil	Nil	697 473	2 098 247
1909....	934 274	56 734	Nil	Nil	991 008	3 179 358
1910....	1 075 026	79 206	4 835	Nil	1 159 067	3 906 478
1911....	909 359	38 005	5 000	Nil	952 364	3 184 057
1912....	954 320	103 382	Nil	Nil	1 057 702	3 349 095
1913....	1 097 208	120 691	Nil	Nil	1 217 899	3 870 841
1914....	703 670	47 705	341	Nil	751 716	2 356 517
1915....	873 422	70 147	834	Nil	944 403	2 970 526
1916....	1 402 859	61 712	346	Nil	1 464 917	5 571 429
1917....	1 313 708	40 816	1 487	Nil	1 356 011	7 381 333
1918....	859 188	40 782	Nil	Nil	899 970	5 802 870

The figures for 1880 and 1890 are taken from the reports of the United States census; from 1891 to 1903 they are extracted from the annual volumes of the *Mineral Resources*.

It will be noted that the output in the last few years has shown an expanding tendency and is now practically on a parity with the production during the earlier period when most of the ore was smelted locally instead of being shipped to Pennsylvania furnaces. The value of the product in 1914-18 amounted to over \$21,000,000, and the total of \$7,381,333 reported for 1917 exceeded that of any previous year. The prices received for ores during this period were above the average on account of war conditions.



Distribution of Iron Ore

The following is a brief summary of the principal features relating to the distribution and occurrence of iron ores in New York State.

The workable deposits are found in the following areas or districts:

1 **Adirondack region.** Magnetite ores with locally associated hematite (martite) in Precambrian acid igneous rocks; also in schists and gneisses of sedimentary origin. Mixtures of magnetite and ilmenite (titaniferous ores) in basic igneous rocks of the gabbro-anorthosite class, intrusive in the older gneisses.

2 **Highlands of the Hudson.** Magnetite in Precambrian gneisses, in acid igneous rocks and along the contact of igneous rocks and limestones.

3 **St Lawrence and Jefferson counties.** Hematite associated with Grenville limestone and schist, as replacement bodies.

4 **Central and western New York.** Fossil and oölitic hematite, interstratified with Clinton limestones and shales in horizontal beds.

5 **Dutchess and Columbia counties.** Limonite associated with crystalline limestones, slates and schists, representing metamorphosed sediments of early Paleozoic age. Siderite, or carbonate of iron, accompanies the limonite in many places and in one or two of the mines is the principal ore. The deposits are secondary or of later age than the inclosing rock.

6 **Staten island.** Limonite in residual accumulations resting on serpentine.

1 Adirondack Region

The principal magnetite deposits low in titanium are found on the borders of the Adirondack highland, in Washington, Warren, Essex, Clinton, Franklin and St Lawrence counties, in the eastern, northern and northwestern sections. On the southern and western sides there are few bodies and these have yielded little ore.

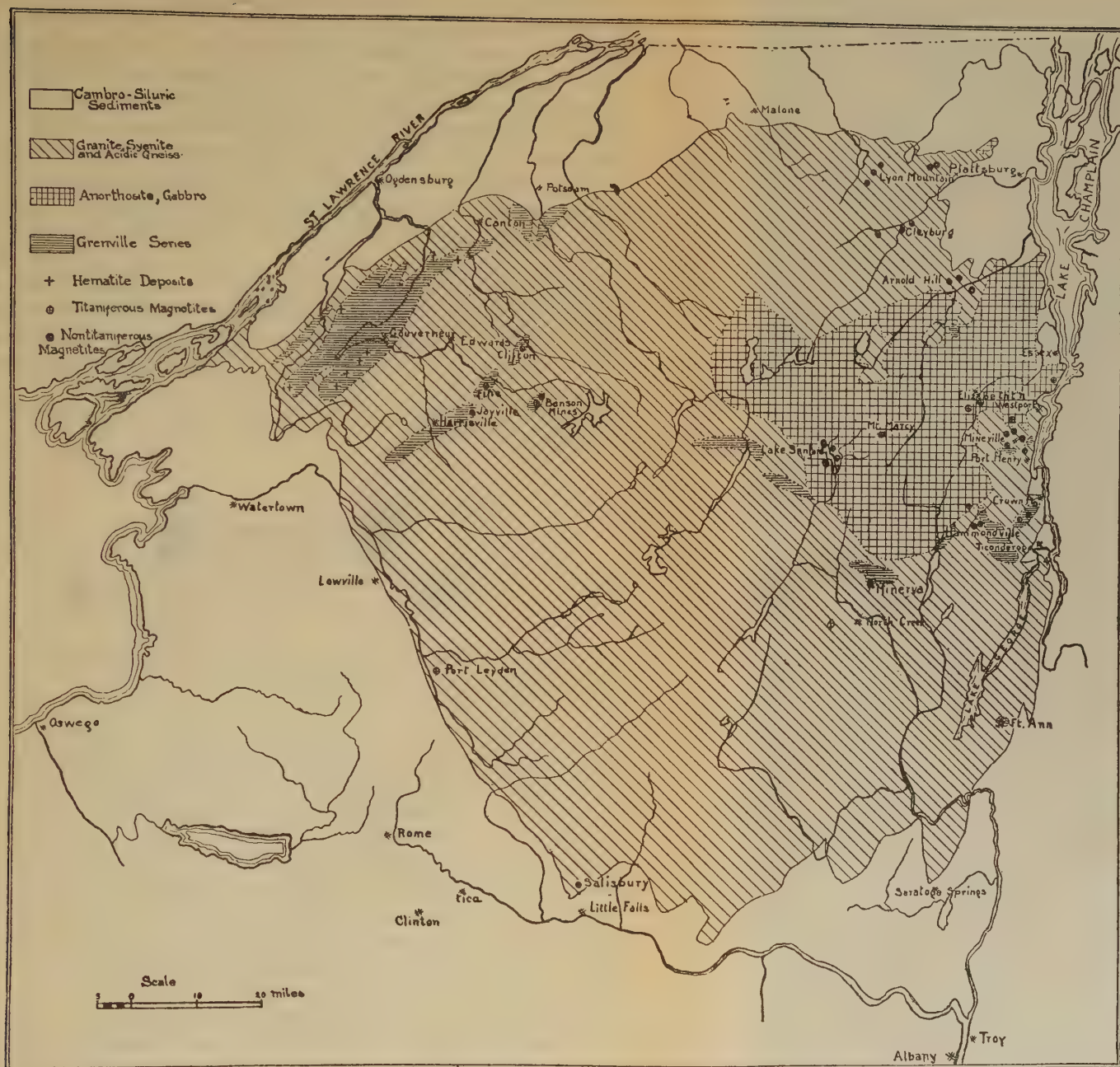
The country rocks are varied in character but in the greater number of occurrences they consist of a light colored massive or gneissic rock which corresponds to granite or syenite in mineral composition. The feldspar is usually an intergrowth of potash (microcline) and soda (albite) varieties, and is associated with moderate to small amounts of quartz. The dark minerals are represented by diopside and hornblende, usually in small amounts. The textures and general habits of the gneisses are frequently those of igneous rocks. In St Lawrence county, however, the magnetites are found in banded rusty gneisses containing more or less sillimanite, closely allied with Grenville rocks to which they may belong. They may have limestone on one of the walls. It seems probable therefore there are at least two classes of deposits — the one characterized by their occurrence within the body of igneous rocks and regarded as original segregations within the magma; and the other associated with gneisses and schists which are doubtless old sediments. Of the latter class the derivation of the deposits is uncertain, as they may be held to be contemporaneous with the wall rocks or later migrations into their present surroundings, superinduced perhaps by the agency of neighboring igneous invasions. The occurrence of secondary garnet, hornblende and pyrite is characteristic of this class of magnetites.

In shape the magnetite deposits vary greatly; they are commonly described as veins, lenses, pods etc., according to the particular

features exhibited in individual instances. They are not veins in a genetic sense, although they often show a tabular development with sharp boundaries against the country rocks, in common with secondary vein deposits. Some of the occurrences extend for several miles along the strike, although in such cases the magnetite is distributed among separate bands or lenses arranged in series, end to end or overlapping to some extent, the whole constituting an ore zone. The Lyon mountain, Palmer hill, Arnold hill and Cook hill deposits in Clinton county, the Barton hill-Fisher hill series at Mineville and the Benson Mines series in St Lawrence county illustrate this method of occurrence. Not infrequently the deposits assume very intricate forms, like the body opened by the 21-Bonanza-Joker Mines at Mineville, which are hardly explainable as the effects of regional compression and folding upon original lenses or tabular deposits. Rather they point to inherent irregularities assumed in the process of magmatic segregation.

The ores range from rich magnetites, with 60 per cent or more of iron, through all gradations down to very lean mixtures of magnetite and gangue minerals—in fact the lower limit is reached in the ordinary country rocks of syenite and granite which contain a few per cents of free iron oxides in the form of magnetite. The richer ores are likely to contain moderate to high amounts of apatite, as much as 10 per cent in Mineville Old Bed product, so that they are more employed for foundry and basic pig. The leaner ores which require beneficiation by crushing and concentration are relatively lower in phosphorus content and many come within the class of Bessemer and low-phosphorus ores. The Chateaugay mines afford an exceptionally desirable product, comparable to the best Swedish ores in regard to phosphorus and sulphur.

The titaniferous ores, mixtures of magnetite and ilmenite in varying proportions, are associated with the low-silica or basic igneous rocks and represent segregations of the heavy constituents of the magmas while in a fused state. The largest bodies occur in the great anorthosite batholith that constitutes the central and eastern Adirondacks, the region of greatest surface relief. They are also met with to some extent in the smaller bosses and dikes of gabbro that border this area. A singular example, occupying an intermediate position between these ores and the normal magnetites, is represented by a deposit near Port Leyden, Lewis county, within syenite gneiss and with a content of about 10 per cent titanite oxide. The average for the other deposits is from 15 to 20 per cent titanite oxide.



The Adirondack region. Distribution of the principal geologic formations and occurrence of the iron ores.

The available resources of the titaniferous ores are very large. The principal deposits are near the headwaters of the Hudson river, on the southern slopes of the Mt Marcy group, Essex county, where in an area of a few square miles are exposed a number of great ore bodies whose possibilities are to be estimated in tens of millions of tons. The iron content ranges from 40 to 60 per cent and the phosphorus usually is below the Bessemer limit. By crushing and treating magnetically it is possible to effect a separation of the magnetite and ilmenite, thereby reducing the proportions of titanic oxide in the concentrates to one-half or less of that present in the crude ore.

A brief description follows of the more important individual magnetite districts in the Adirondack area. Further particulars may be found in New York State Museum Bulletin 119, "Geology of the Adirondack Magnetic Iron Ores."



Section across the Penfield pit, western portion. Pegmatite developed along axis of fold

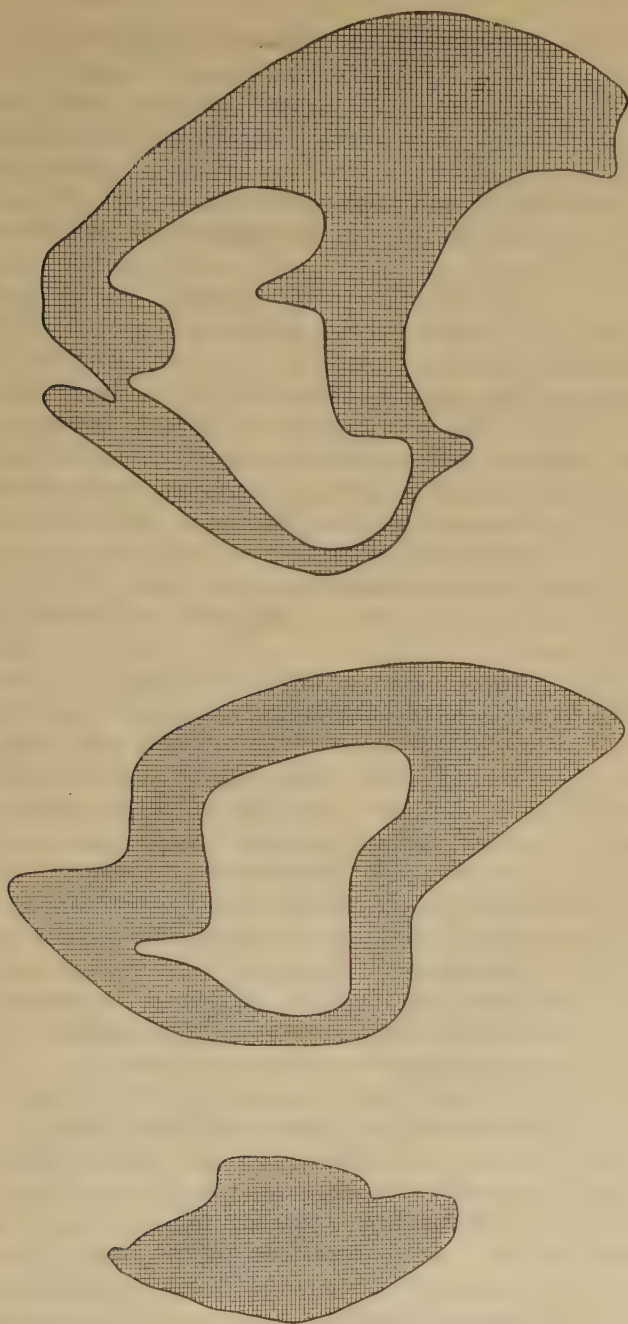
Hammondville. This locality 13 miles west of Crown Point on Lake Champlain, the nearest railroad point, has supplied 2,000,000 tons of mostly Bessemer ore. The mines were closed in 1893 during the period of extreme depression in the Eastern iron trade, and all the equipment has been removed from the property. It is known, however, that considerable resources still remain. The magnetite is restricted in occurrence to a light, finely granular gneiss which outcrops over an area $2\frac{1}{2}$ miles long by $1\frac{1}{2}$ miles wide and resembles somewhat in its general character the Mineville ore-bearing gneiss which is regarded as a phase of the granite-syenite magma. In all about thirty different openings exist in as many ore bodies; the deposits of most importance are the Penfield and adjacent West End, the Hammond, Dog Alley, North and No. 7, of which the Penfield ranks among the larger bodies of its kind in the Adirondacks,

having an outcrop length of 1000 feet and affording breasts of ore 30 feet high in places. The deposits exhibit rolls, swells and pinches and remind one very much of the involved structures found in the Mineville occurrences. Mining operations were complicated by these features and by the distribution of the ores among so many separate bodies which are distributed over about a square mile. The property was under examination by the Oliver Mining Co. in 1906, which located some unmined bodies with the diamond drill. The magnetites as mined contain from 50 to over 60 per cent iron, with quartz as the principal gangue, are free of sulphur and hold a few hundredths of a per cent of phosphorus.

In the vicinity of Hammondville, on separately owned properties, are the Skiff, Long pond, Schofield and Paradox lake mines of smaller size.

On Reed mountain near Crown Point village and southwest of there pyritic magnetite occurs in several places.

Mineville. The most productive deposits of the Adirondacks are at Mineville; the output of the two companies, which have operated the mines from the start — Witherbee, Sherman & Co. and the Port Henry Iron Ore Co.— exceeds 1,000,000 tons in active years, the largest for any iron ore district in the east. The main resources for a long time was the 21-Joker-Bonanza group of mines based on a single great “horn” of ore, 2000 feet or so in length, composed of an enveloping body of magnetite about a core of the country gneiss, the whole laterally compressed and parts drawn out into wedgelike extrusions so as to afford a constantly changing section. The outlines of the body as first surmised from the features revealed by development and test drilling have been considerably modified with the progress of exploration and mining which now have established practically the full contours. The main ore supply has been nearly worked out, in fact practically only the pillars are left, which of themselves represent a large tonnage that awaits possible recovery. A separate and extensive ore body was found to lie below the Joker-Bonanza deposit taking the form of a slightly inclined tabular mass which pitches to the south with the other and yields a similar high-phosphorus magnetite. This body has been exploited by sinking in the Joker-Bonanza workings. It reaches to the south beyond the limits of the latter deposit.



Cross-sections of the Joker-Bonanza magnetite deposit, Mineville, showing change of form along the axis. The "horse" of country rock shown in the upper sections disappears before the ore comes to an end.

The Harmony deposit to the south and a little west of the Joker-Bonanza has developed into a large producer. It consists of a sheet of ore where first tapped by the shafts, having a rather flat dip to the southwest, but as it is followed downward rapidly steepens and is cut by small trap dikes along faults of slight displacement. It lies considerably higher than the Old Bed and affords a different quality of ore, lower in iron and phosphorus and having a quartz gangue.

The Barton hill mines are opened along an ore band that shows swells and pinches but is practically continuous for 3500 feet, beginning one-half of a mile directly west of the 21 opening and running a little east of north along the southern and eastern slopes of the hill. After an interval of 2000 feet of unworked ground ore again appears on Fisher hill and extends for another 2000 feet. The Barton hill deposits were mined in the early days when a large quantity of furnace ore was shipped from the higher grade portions and are now being worked systematically with removal of all the material that can be treated profitably in the mill. The concentrates are below the Bessemer limit in phosphorus and highly desirable for furnace use.

The Smith mine owned by Witherbee, Sherman & Co. lies to the east of Fisher hill; it has been worked at intervals, but not on a large scale. The Sherman mine is one-half of a mile north of the workings on Fisher hill and is the last of the Mineville group encountered in that direction. It is one of the old mines but has recently been reopened and put in regular operation.

Three mills employing dry magnetic concentration are operated on the Mineville ores, and in addition some of the output is shipped crude. From the Old Bed ore, a valuable apatite product is secured, serviceable for phosphate manufacture. The surface and underground installations exemplify the highest development in the technic of mining and milling and have been adopted as pattern in many of the other magnetite districts of the east.

Between Mineville and the lakeside north of Port Henry are the Pifershire and Lee mines, long since inoperative; while on the lake 2 miles north of Port Henry is the Cheever mine, the oldest in the district on which work was restarted in 1908, after a long period of idleness. This belongs to the Cheever Iron Ore Co. It is based on a sheet, showing in some places two parallel layers, that extends for nearly a mile on the outcrop, included in a grayish or greenish quartz syenitic gneiss overlain by limestone and having gabbro on the east side toward the lake. It yields an ore high in phosphorus

and of granular texture, resembling the Old Bed at Mineville. The ore is mixed with feldspar and quartz gangue and shades into the country rock in the walls but has rich bands in the middle. It is all concentrated. The principal work recently has been within the southern section opened through the Tunnel, Weldon and Witherbee shafts, and has consisted in the extension of the old workings and removal of the large quantities of lean material left in the walls. There is a considerable area of unmined ground farther north which will constitute a reserve for the future and also possibilities of extending the productive territory to the south.

Ausable Forks. In the region north and east of Ausable Forks, in southern Clinton county, is a group of magnetite bodies which taken in the aggregate represent one of the largest accumulations of the kind in the whole Adirondacks. The ore-bearing district comprises the series of prominences on the north side of Ausable river between Ausable Forks and Clintonville, a distance of 5 miles in a direction a little north of east and reaches back or north for a distance of 3 to 5 miles. This district was the scene of many small-scale operations during the period from 1825 to 1890, the ore output being used locally for bloom iron at forges situated at Clintonville, Ausable Forks, Black Brook and Jay. The total output could not have fallen much short of 2,000,000 tons and may have exceeded that figure.

Most of the ore properties have been acquired in the last few years by Witherbee, Sherman & Co. with a view to the eventual reestablishment of mining on a modern basis. As a preliminary, extensive exploration has been carried out, mainly on Cook hill, north of Clintonville and on Palmer hill and the adjoining territory to the north, which has brought to light much new information about the distribution of the magnetites and greatly increased the known resources. The separate deposits are developed as lenses, shoots and tabular bodies, arranged in series so as to constitute some three or four distinct ore zones. There is thus the Cook hill group, made up of the Winter, Mace, Cook, Battie and other openings which forms a practically continuous series, beginning within a mile or so of Clintonville and extending some 3 or 4 miles to the north. The deposits are comparatively thin, 10 to 30 feet for the most part, but their great length and probable depths make the resources very large.

On Arnold hill next west is another group that contains two or three parallel series that have been explored for $1\frac{1}{2}$ miles altogether, with the Nelson Bush and Arnold mines as the largest producers.

Some of the bodies in this group carry large proportions of martite whose presence is revealed by the bluish tint of the ore in mass; the shape usually is rudely lenticular, widest in the middle and narrowing down or pinching out where followed along the strike and pitch, but the continuation of the ore is then to be looked for along the same course or at a short distance to one side or the other of the axis. The maximum width is about 25 to 30 feet. Slight offsets are caused occasionally by dip faults.

On the west end of the district are the Palmer hill, Jackson hill and outlying bodies farther north, forming a belt some 3 or 4 miles long, but with important breaks in which no mineralization is observed. Palmer hill, a bare prominence 2 miles north of Ausable Forks, is traversed by a band of magnetite that has been explored for over 2000 feet along the strike and to an extreme depth of 2200 feet, with a yield probably of between 1,000,000 and 1,500,000 tons. Here in 1836 was installed the first magnetic concentrator to be operated in the Adirondacks; it was a crude device, made up of a series of horseshoe magnets arranged in the interior of a revolving drum, but an interesting anticipation of the present day mills. The magnetite occurs mainly in disseminated condition in the country rock which is massive granite low in quartz and containing more or less fluorite; but rich shoots were met with in the early days and these supplied most of the output. The ore is of Bessemer grade. Jackson hill is a mile northeast of Palmer hill; parallel bands of magnetite occur in similar associations but are narrower. Still farther north on Hogback mountain is a series of deposits very little exploited hitherto, but which recent tests with the drill have proved to contain large resources. The ore is higher in phosphorus than the usual magnetites of the district.

Saranac valley. A group of deposits in the towns of Saranac, Black Brook and Dannemora once supported an active mining and metallurgical industry in towns along the Saranac river. One of the more extensive series of workings is in the vicinity of Redford and Clayburg on an ore zone which is traceable by outcrop and magnetic attractions for 6 or 7 miles. At the Bowen & Signor mine, just south of Redford, the ore has been mined for 1600 feet on the first level and varies from 20 to 30 feet wide. The crude ore is non-Bessemer but is said to yield Bessemer concentrates. It carries around 40 per cent or a little less of iron. Above Clayburg is an extensive working, now largely caved, which shows about the same grade of magnetite. In the vicinity of Dannemora village is another series, including the Fairbanks, Ellis, Averill and Danne-

mora mines based on long bands which as a maximum are about 30 feet thick.

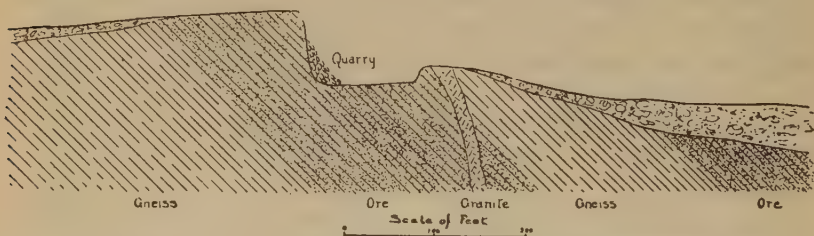
Lyon mountain. The ore bodies now mined represent the middle section of a belt some 5 miles long extending along the lower slopes of a ridge of which Lyon mountain is the culmination. The trend in general is northeast-southwest. On the southwest end is Mine 81, 2 miles from the main group, opened for about 1000 feet along an ore band that averages 18 feet wide and is nearly vertical. It has been idle since 1902. The ore is higher in phosphorus than the present product, but affords good Bessemer concentrates. In the main group which lies directly on the flank of Lyon mountain three more or less well-defined seams are shown in outcrop or by mining development, occupying a zone about 200 feet across. The front or main deposit is the chief dependence in mining and has been opened for a distance of 2500 feet on the strike and explored still farther by test pits. Its strike throughout most of its course is N. 20° E. but in the southwest section, near shaft 5, the course swings around in a broad curve to nearly west, and the ore body shows a notable thickening as well as flattening of the dip so that much ore has been removed by open cut operations. Elsewhere the dip ranges from 45° to 60°, steepening toward the northeast, and the ore measures about 20 feet from wall to wall. Underground work in the past has been carried on through a large number of inclined shafts or slopes, some of them poorly planned for permanent work; a new central shaft has been put down lately, of ample capacity to replace the numerous small ones previously employed, and a systematic method of development has been laid out. A large modern mill is also in course of construction. On the northeast end of the ore belt, 2 miles away, is the Parkhurst shaft, now inoperative.

The ore occurrence is very similar to that described for the deposits near Ausable Forks. The country rock is gneiss composed of feldspar, quartz and minor amounts of diopside and hornblende, with pegmatitic and aplitic phases, a slightly foliated granite or acid syenite in field appearance. It carries considerable magnetite in disseminated condition, often showing schlieren quite as rich as much of the ore itself. The latter shows a wide range in regard to iron content, but the mine average is around 30 per cent. In the first operations considerable quantities were shipped in lump form but now all the product is sent to the mill.

The Lyon Mountain mines belong to the Chateaugay Ore & Iron Co. which took over the property in 1903. Since 1871 when the first regular operations began it supplied about 5,000,000 tons of

furnace ore and concentrates. The ore is of a most desirable quality on account of the low proportions of phosphorus and sulphur. The run of concentrates averages around 65 per cent iron, with from .005 to .01 phosphorus and an average of about .008 phosphorus.

Benson Mines. Large deposits of low grade magnetite inclosed by a banded garnetiferous pyritic gneiss are the basis of mining at this place which has recently been resumed after several years inactivity. The deposits are found along a zone that lies near the base of a low ridge and that begins apparently about a mile west of the railroad station and trends first to the southeast and then swings around to the northeast and east-northeast which direction it follows for most of its course. At the pits by the station the trend is N. 60° E. Beyond there it can be traced by magnetic readings for some distance across the highway and brook, but seems to die out within a few hundred feet of the brook. The ore at the pits has a dip to the southeast of about 45° and the open cut is about 200 feet wide and over 1200 feet long (1915). No underground mining has been undertaken.



Benson Mines. Section across the ore bodies, near middle of quarry

The occurrence belongs to the disseminated type like the Lyon mountain, but differs materially from the latter in many respects. The country rock is a mixed gneiss, of which the base seems to be a part of the Grenville or sedimentary series, while it contains much granitic material injected and diffused through the mass. The magnetite is fine grained and held in a matrix of garnet, feldspar, quartz, sillimanite and pyrite. The granite injection is accompanied by pegmatite phases which also carry magnetite.

The ore carries about 30 per cent iron on the average. In crude state it has too much sulphur to be desirable for the furnace, but this is removed partly in concentration, while the phosphorus is also reduced by the process. The concentrates after agglomeration in the kiln yield an excellent Bessemer product. A process of wet magnetic concentration has been employed in the recent work.

The mines up to the present have shipped only a few hundred thousand tons; the ore supply, however, is very extensive and under favorable market conditions should be actively and profitably exploited.

Clifton. About 10 miles north of Benson Mines are the Clifton deposits which include a group of ore bands and lenses in hornblende schist and along the contact of this rock and limestone, with a red granitic gneiss extensively developed nearby that is intrusive in the schist. The ores are sulphurous, made up of magnetite in a gangue of hornblende, biotite, garnet and quartz, with pyrite and pyrrhotite in varying amounts. The principal openings are on the Dodge vein which has a width of 20 feet. Concentration would be necessary for most of the material, as the average content is probably under 40 per cent. The deposits were once worked by the Clifton Mining Co., and a furnace at Clarksboro was run for a time on the product. The Parish ore body is north of this on Tracy pond outlet. It affords a granular magnetite, free of sulphur, but containing some garnet. It has not been explored to any extent, although the magnetic attraction seems to indicate a considerable mineralized area. Other deposits in this part of St Lawrence county are in the town of Fine on the ridge limiting the Oswegatchie river, 4 miles northwest of Oswegatchie village, and those at Jayville on the Carthage & Adirondack Railroad, 14 miles west of Benson Mines. The latter has been under exploration recently, but were last operated actively 30 years ago. They consist of lenses and irregular bunches of magnetite along the contact of Grenville gneiss and granite, and are accompanied by abundant hornblende.

Lake Sanford. Since the publication of the bulletin on the Adirondack magnetites in 1908, the titaniferous ores at Lake Sanford have undergone extensive exploration by the MacIntyre Iron Co. The known resources have been enlarged enormously by tests with the diamond drill which have demonstrated the continuity of the deposits in depth already known to cover large areas. Experimentation in the smelting of the ores in the blast furnace on a commercial basis was carried out in 1914 at Port Henry. Tests indicated that no special difficulties are to be anticipated under normal furnace practice, with charges containing one-third or one-fourth of the titaniferous material in mixture — the limit to which the tests were carried. The slags actually were more fluid than normal slags. The pig iron contained about one-half of 1 per cent titanium and a maximum of .1 per cent vanadium. There seem to be no insuperable technical obstacles in the way of exploitation and utilization of these ores, and it would be a great economic gain to have them developed.

2 *Highlands of the Hudson*

The belt of Precambrian gneisses which crosses southeastern New York from New Jersey to the Connecticut boundary, occupying a large part of Orange, Putnam and northern Westchester counties, contains many magnetite bodies that have been mined on a small scale, altogether constituting a resource of considerable importance. The deposits are strung out along a northeast-southwest axes parallel with the general structural trend. Geologically they exhibit a wide range of features and are also varied in their mineral and metallurgical characters.

The gneiss belt is composite, with some types certainly of igneous derivation and others that are very likely sedimentary. The igneous members include granitic, syenitic and dioritic gneisses, accompanied usually by more massive pegmatitic phases. Throughout the Highlands there is extensive development of pegmatitic granite in bands, schlieren and small bosses and it is almost invariably encountered in the vicinity of the magnetites. Of the sedimentary gneisses there are very few areas where they are exposed in unmixed development, for nearly everywhere they are interleaved and injected by magmatic material of similar nature to the larger bodies of igneous gneisses. Their usual habit is a banded one, with alternating layers of lighter and darker color corresponding to variations in mineral composition. Some layers are nearly pure quartz, and others are largely hornblende or mica, or a mixture of these with feldspar and quartz. These sedimentary gneisses may include more than one stratigraphic group, as their areal relations have not been fully studied, but in many places they may be said to show close resemblance to the Fordham gneiss that is extensively developed in southern Westchester county and that has been classed by Berkey as early Precambrian and likely equivalent to the Grenville gneiss of the Adirondacks. Small bodies of crystalline limestone accompany the gneiss and are to be regarded as a part of the same sedimentary series. The igneous intrusions in the Highlands belong mainly to the early Precambrian and have undergone compression and extensive structural rearrangement. The Cortlandt series of basic intrusives lies on the southern margin of the Highlands proper and has not shared in the general metamorphism, being of Paleozoic age.

The magnetites, hitherto mined, have been shipping ores with from 50 to 60 per cent iron. These are not yet exhausted, although the main supply for future mining consists of concentrating ores which carry upward of 25 per cent iron and which can be worked on an extensive scale. The richer magnetites, with few exceptions

like the Sterling, Forest of Dean and Tilly Foster occurrences, are in thin beds 10 to 15 feet thick at most and consequently the economic limit of exploitation was reached at shallow depths under the conditions of mining that formerly obtained. In all there are probably over 50 of these smaller bodies that have been worked in the past. The aggregate output of shipping ore has been approximately 6,000,000 tons.

Sterling Lake. The output at Sterling Lake is now taken from a single deposit, known as the Lake, one of the numerous bodies that occur in the vicinity and that together have supported a mining industry for the last 150 years and more. The different deposits vary greatly in their physical features as related to form and content, although situated in the same general geological surroundings, so far as cursory examination shows. Some are thin sheets lying flat, or slightly inclined, others are attenuated lenses with a moderate to steep dip and usually with a pitch to the north, and still others are developed as narrow, elongated shoots with the long axis on the pitch which likewise is to the north. More complex forms result from differential compression and folding of these simpler types.

The principal deposits lie within a belt that begins near the New Jersey line and extends some 5 or 6 miles to and beyond Sterling Lake. It is a part of a much larger ore zone that reaches into New Jersey on the south and extends in a general northeasterly direction across Orange county to the Hudson river. Beginning at the south, within a short distance of the state line, the series include the Steel mine which outcrops on a ridge at about 800 feet A. T. and is based on a band of ore striking N. 20° E. It is opened by a few pits on the south end. The same band of ore extends north beyond the hill under the adjoining valley. The next deposit is the Crawford, located on a lens which begins near the base of the succeeding ridge and pitches northward under it; it is opened as a pit and underground drift for a distance of 500 feet on the strike. It measures 20 to 40 feet in width from wall to wall, but includes bands of lean or barren gneiss intercalated with the magnetite. An interesting feature of its geology is the fact that the ores cut obliquely across the bedding of the gneiss. The presence of massive granite on the eastern or hanging side (the dip is about 75° E.) may be noted, whereas the foot wall consists of the usual hornblende gneiss. The granite on the north end also caps the ore body. Another lens lies a little west of the Crawford and is open in the Brennan pit. It trends northwest.

The California mines are about 7000 feet farther north, on the opposite side of the ridge on which the Sterling and Lake deposits

outcrop and about one-half of a mile distant from these. They are based on a thin but persistent band of magnetite that lies nearly flat and outcrops on the southern and southwestern sides of the hill. The ore is of Bessemer grade, whereas the Lake and Crawford mines contain too much phosphorus to come in that class. The California ore band reappears on the northwest side of the ridge where it has been worked through the Tiptop mine.

The Sterling and Lake mines, of which the latter is now the only active producer on the property, are opened on two long lenses or shoots which outcrop on the side hill at the foot of the lake and extend north under the latter at an angle of 28° for the Sterling and 23° for the Lake body, measured on the average inclination of the respective slopes. Both dip to the east, although rolls occur which locally reverse the normal dip. The Sterling mine is down 1000 feet and has not been worked since 1902. The Lake slope is over 3200 feet in depth. The two slopes are 500 feet apart at the surface and pursue a slightly divergent course. From the presence of numerous pinches and minor rolls in the Lake mine, it might be reasonably maintained that the two bodies are parts of one original deposit which has been squeezed out into the present form. It has been the prevalent opinion, however, that they are separate and distinct deposits, and the Lake, if it were continued on the dip, would lie above Sterling deposit. For a distance of 2300 feet on the slope, granite forms the hanging wall of the Lake slope, but at that depth gives way to hornblende gneiss. The Lake mine has yielded over 1,500,000 tons of shipping ore up to the present time. The ore runs about 57 or 58 per cent iron and 1 per cent or so of phosphorus.

To the east of Sterling lake about 5000 feet is a series of lenses that lies along a nearly north-south axis, on which are located the Crossway, Mountain and Smith mines. They are within the town of Tuxedo but close to the Warwick line. About 800 feet farther east a second series, with openings known as the Augusta, Cook, Scott, Oregon and Long mines, occurs along a parallel axis measuring 6500 feet from south to north. They all have an easterly dip and northerly pitch and have been worked by open cutting or by drifting under cover. The Cook mine, however, was worked through a vertical shaft and had underground connections with the Scott deposit, which also was tapped by a slope. There is little of the early workings in this part now accessible, but the ore as seen in places near the outcrop measures up to 25 feet thick.

To the south and east of the Augusta, higher up on the ridge which lies across the town line and near Tuxedo lake, is the Redback'

based on an ore band that extends for over a mile on a course a little east of north. The band is straight, regular and over a mile in length. Its outcrop is marked by a reddish color, which arises from oxidation of the sulphides that are intermixed in small proportions with the magnetite. The deposit is rather thin, not over 10 or 12 feet in most places, but no doubt contains a large quantity of ore. On account of the sulphur content it has not been exploited in any large measure, although some ore was produced in earlier years for furnace use, having been roasted on the ground. A sample representing the crude material as mined is stated by Putnam to have contained 52.93 per cent iron, .028 phosphorus and 3.603 sulphur.

The Morehead, Bering and Sloatsburg mines were opened in different bodies that lie in the area between Sloatsburg and Tuxedo lake. The Sloatsburg mine is in Rockland county. None of these has been worked in recent years and little is known as to their extent or as to the character of the ores.

Altogether the resources in the Sterling Lake district are undoubtedly very large. So far only the richer and more available ores have been attacked, as the concentration of the low grade material has not been attempted; there is no reason to believe that any of the mines have been bottomed and in most instances the supplies have not been seriously drawn upon. In view of its favorable situation and the extent of the resources, the district should take a prominent place in the future mining industry of the State.

Warwick. A group of ore bodies, on which are located the Rayner, Taylor and Standish mines, now inoperative, lies $2\frac{1}{2}$ miles south and a little east of Warwick, Orange county, on the ridge of gneiss between there and Greenwood lake. The Standish mine is based on a thin seam, not over 2 to 8 feet thick as opened, which can be traced for one-half mile on the outcrop. In one place it is split by a horse of the country rock, a well-laminated biotite gneiss heavily injected with pegmatite. The seam strikes N. 30° E. and stands vertical or inclined at a high angle to the southeast. At the northeast end it is faulted by a dip fault, beyond which the ore is not again in evidence. The magnetite carries some pyrite, but is fairly high in iron. The mine was last worked about 1880 by the Parrott Iron Co.

The Rayner is west of the former, across the highway on a ridge. It is widest toward the northeast where it was opened by a shaft, now caved, and there open cuts show 6 to 10 feet of ore in nearly vertical position. To the southwest along the trend it becomes a double bed through the appearance of a seam of gneiss that increases

up to 30 feet wide. The ore is coarser and more pyritic than that of the Standish. The deposit was worked by the Warwick Iron Co. which ceased operations about 30 years ago. Southwest of the Rayner is the Centennial mine which lies across the New Jersey line.

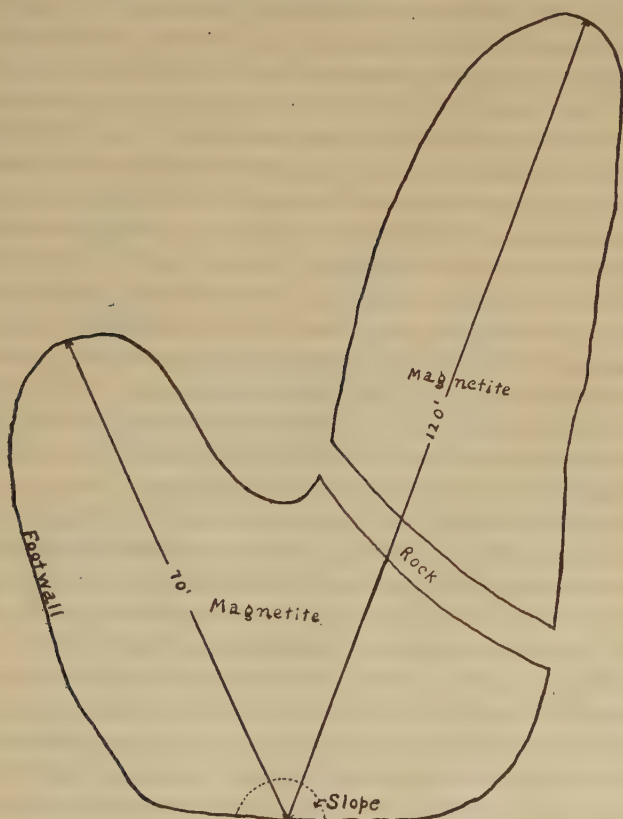
Monroe. About $2\frac{1}{2}$ miles south of Monroe near Lake Mombasha are the Forshee, O'Neil and other ore bodies which are mentioned by Smock and Putnam as having been worked in 1880, but have long since been closed. The O'Neil mine is notable geologically as being based on a contact deposit in which limestone has been altered to a variety of minerals including chondrodite, serpentine, hornblende, epidote and garnet, affording relations very similar to those at Tilly Foster mine. The ore is lean and large quantities of waste had to be sorted in the production of furnace ore.

Forest of Dean. This is one of the oldest mines in the Highlands. It has been under operation since 1756, although not continuously, and has reached a depth of 4100 feet on the axis or pitch of the ore which gradually diminishes from 27° near the surface to about 19° at the bottom. In that distance the deposit has maintained its character and general form almost unchanged. A section across the axis shows two wings which diverge above, separated by a wedge of coarse reddish granite; they merge below into a single mass that measures 80 feet across and 50 to 65 feet high from the bottom to the granite horse. The shape may be likened to a synclinal fold with the two wings of the fold abruptly truncated, as shown in the accompanying figure which is adapted from a sketch supplied by Mr H. P. Sweeny, superintendent of the mine. On the outcrop the deposit appeared to be a double vein, the two bodies having a band of granite between, and it was so figured by Mather in his report for the First Survey. Below the surface, however, the body assumed its present proportions and form. The wall rock is biotite gneiss with a northeasterly strike and southeasterly dip, but limestone appears on the footwall side not far away. The pitch of the ore is also northeast, while the footwall approximately conforms to the dip of the gneiss. A band of rock from $1\frac{1}{2}$ to 8 feet thick, whose exact nature has not been determined, cuts across the southeasterly wing near the base.

The ore is granular magnetite, often of friable texture and resembling the magnetites of the eastern Adirondacks. Small crystals of apatite are in evidence and the ore is all of non-Bessemer grade. The content of iron averages about 60 per cent. Some sorting is necessary on account of admixture with granite which is found in stringers and small bodies within the deposit and is of the same character as the granite that divides the two wings of the

deposit. It is composed of pink and green feldspars and quartz, with magnetite as the only dark ingredient of importance. The gneiss country is permeated by the granite which is to be seen also in independent bodies. Apparently the deposit has been a locus of igneous activity, a feature that characterizes practically all of the magnetites in Highland region. Several trap dikes occur in the vicinity. The largest is about 6 feet thick and crosses the ore body diagonally, disappearing into the footwall with depth. They have been described by Prof. J. F. Kemp as belonging to the camptonite class of dike rocks. They are much later in age than the granite.

The Forest of Dean mine is worked by the Fort Montgomery Iron Corporation which a few years ago succeeded the Hudson Iron



Approximate section of the Forest of Dean magnetite deposit

Co. The present period of activity dates from 1906. The output is carried by a tramway and aerial conveyor 5 miles to Fort Montgomery on the Hudson river where there are facilities for shipment by rail and boats. No records exist of the production for the earlier years, but the entire output can hardly be less than 2,000,000 tons.

Canada mines Group. A persistent belt of magnetite is found in Putnam county, 6 miles east of Cold Springs along Canopus creek, south of the Carmel road. The northern section, of about a mile length, is known as the Canada mines which consist of prospects and shallow pits on the outcrop of a seam that strikes N. 40° E. and dips steeply to the southeast. The deposit, where exposed, shows 3 to 15 feet of magnetite in a single seam. The middle portion is mostly solid ore, but toward the walls the magnetite is in narrow ribbons or strips alternating with gneiss, the layers of rock increasing in thickness outward. There is much pegmatite in the vicinity and it may constitute one or both walls for some distance, but normally the magnetite is in direct contact with the gneiss. The latter is a grayish hornblende-biotite variety which develops locally into amphibolite and along the ore belt shows alteration to epidote. There are small offsets to the seam from transverse faults, nowhere more than 50 feet measured on the surface. The body displays remarkable continuity and regularity in outcrop in view of its moderate thickness; that it should persist in depth seems a reasonable assumption, although this feature has not been tested by actual exploration, the old workings being shallow and little more than prospects. Concentration would be necessary to present day exploitation. The mines were a part of the properties in the vicinity owned by the Philadelphia and Reading Coal and Iron Co. who ceased operations here about 1880. The only outlet for the ore was by wagon road to Cold Spring.

To the southwest the ore belt is continued, after an interval of a mile or more in which no openings appear, by the Sunk mines which stretch along a similar ore band for several thousand feet. The outcrop is on the side of the ridge south of the Carmel road facing Canopus creek. The mining development consists of a series of cross adits driven at intervals from the base of the ridge to the ore. At No. 1 on the southern end a shaft was also used in gaining access to the ore below the level of the adit. A considerable tonnage was mined here, as the workings extend for nearly 1000 feet on the strike and to 300 feet depth. The middle portion of about 10 feet was taken out, apparently the richer material, leaving perhaps an equal width of lean magnetite suitable for concentration. It is reported that the mined ore averaged around 54 per cent iron with

phosphorus about .6 per cent. At No. 5 adit a quantity of lump ore was mined and left on the ground. The output of the mines was transported by tramway to the turnpike and hauled in wagons to Cold Spring.

The further continuation of the belt to the southwest has been explored through the Sackett, Pratt and Denny mines in order of occurrence. The Sackett and Pratt lie on opposite sides of the road leading from Dennytown to Canopus creek and each consists mainly of open pits extending along the seam for 300 feet or more. The ore seam measures 5 to 15 feet across, with an additional few feet of leaner material in the walls. As elsewhere pegmatite appears frequently and in places is in contact with the deposit. The ore is identical with that of the Sunk mine. The Denny mine is on the southwest end of the belt, 1 mile southeast of Dennytown, and the workings indicate a more irregular occurrence than shown at the other mines, for the seam pinches and swells so as to form more or less independent shoots or lenses arranged end to end. Little ore was actually mined. The width of the widest part of the lenses is about 20 feet and the length along the strike about twice as great. The property was held independent of the others and was last worked by the Thomas Iron Co.

Nelson mine. An occurrence of magnetite at Travis Corners, 3 miles east of Garrison on the Hudson, may be considered a prolongation of the Canada belt, as it lies nearly along the same axis. It is $3\frac{1}{2}$ miles distant from the Denny mine to the southwest. The property was prospected many years ago by the Kingston Iron Ore Co. and in 1912 was further explored by the Mt Summit Ore Corporation which equipped it with a shaft and small mill. The magnetite occurs in seams interleaved with the country gneiss and to some extent in disseminated condition in the latter; granite has injected the gneiss so as to convert it largely into a mixed rock. The dip at the surface, as indicated by the slope of the shaft is 45° northwest, but becomes nearly vertical at the bottom which had reached a depth of 165 feet in June 1913. The strike is nearly northeast. The heaviest seam of ore is 4 to 5 feet thick. Difficulties were encountered in concentration by the methods employed which made use of permanent magnets set in vertical series with the crushed ore passing as a thin stream in front; much dust was carried down with the magnetite. Little ore was actually shipped and operations were discontinued in 1913.

Tilly Foster. This mine once held a leading place among the magnetite mines of southeastern New York and contributed about

700,000 tons in the period from 1864 to 1897 when it was closed. Its operation was discontinued because of falls of rock which endangered further work and which were occasioned by removal of the roof and pillars in changing from underground to open pit excavation. The deposit consisted of a lens 160 feet thick in the middle, tapering toward either end, and over 500 feet long on the 300 foot level along the major axis which followed the strike of the gneiss east of north. The workings had attained a depth of over 600 feet when production ceased. The geology of the deposit is of great interest on account of the mineral associations; the magnetite while lying in gneiss contains masses of limestone and is itself intermixed with such minerals as chondrodite, spinel, chlorite and serpentine, which indicate contact effects from some nearby igneous intrusion. The same relations hold for the Mahopac mines in Putnam county and the O'Neil mine in Orange county. The ore averaged about 50 per cent iron as shipped and was used for Bessemer pig. The Tilly Foster Iron Co. worked the mine.

Mahopac. The Mahopac Iron Ore Co. developed a deposit in the town of Carmel $1\frac{1}{2}$ miles north of Mahopac Falls which it worked in the eighties of the last century on a considerable scale. The magnetite occurs in an irregular body, described by Smock as four veins or beds which coalesce into two and in places into one bed. The ore was worked for a length of 450 feet and to a depth of about 500 feet. An analysis of a sample of 10,000 tons of the shipping ore is reported to have carried 54 per cent iron, .012 phosphorus and .014 sulphur. A railroad was built to connect the mines with the New York Central lines (Putnam division).

Croft and Todd mines. These are in Sprout Brook valley, a deep long trench in the gneiss area north of Peekskill, eroded apparently along a belt of crystalline limestone. The walls of the valley are gneiss and gneissic granite and the floor is limestone which is rarely exposed on account of the heavy drift mantle. The Croft mine is opened on the west side, 6 miles in a direct line from Peekskill, near the base of the steep ridge which limits the valley on that side. It consists of a series of pits on the outcrop and a tunnel entrance started 100 feet or so below the outcrop to the southeast of it near the highway. The length of the workings is about 700 feet. The seam shows wavelike rolls which cause considerable variations of thickness, but the average is about 10 to 12 feet. The strike is west of north a few degrees and the dip 30° to 35° east. The ore is fine grained and ranges from fairly rich magnetite carrying 55 per cent or so of iron to lean ore with hornblende gangue. Pyrite is present in small amount. Smock states

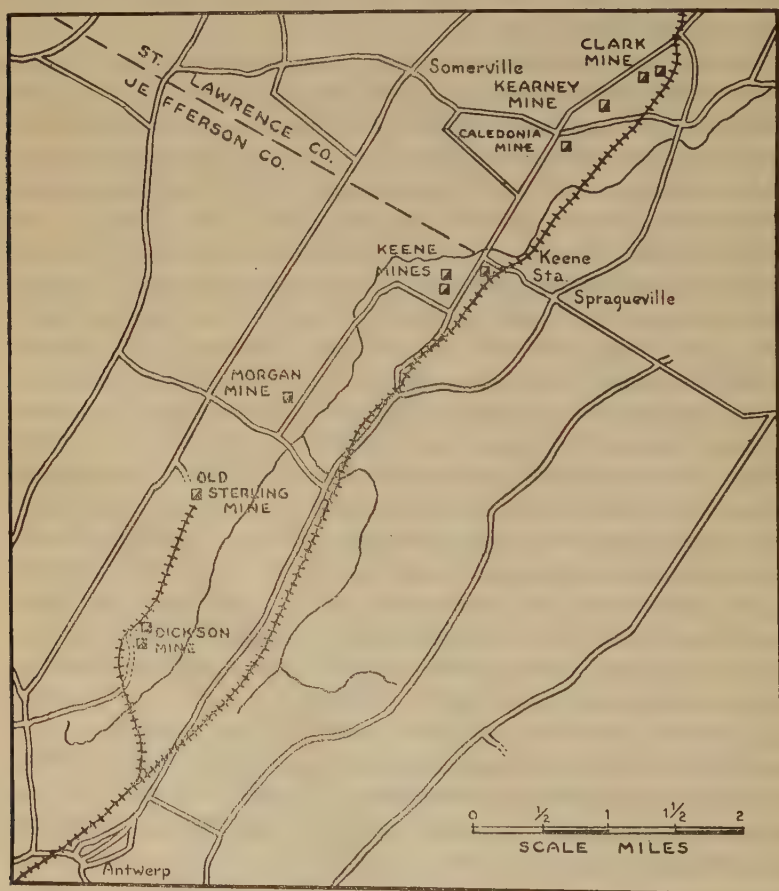
that the product was suitable for Bessemer iron, in which case the ore was probably roasted. The mine was last worked in 1881 by W. H. Campbell. A tramway was used for carrying the ore to the Hudson river at Peekskill.

The Todd is on the same side of the valley 3 miles from the Croft and the same distance from Peekskill. It is near the contact of the crystalline limestone and the gneiss which forms the ridge directly west, and is based on small ore shoots that have been explored in three pits. The eastern wall is limestone while on the west side the ore is bordered in part by fibrous amphibolite schist. The strike of the shoots is northeast and their dip vertical. The ore carries around 45 per cent iron and contains hornblende, epidote and chlorite, showing secondary alteration. The property during the last period of operations (1880) belonged to the Fallkill Iron Co. who operated furnaces at Poughkeepsie. It is now included in the estate of Stuyvesant Fish.

Croton mine. This is a large low-grade property, on an ore zone that extends some 5 miles in a southwest direction from Brewster. The mine is about in the middle of the zone, while the Brewster mine is at the north end and a third working lies near the south end, one-half of a mile west of Croton Falls. Work has been carried on at different times, the last period of active mining began in 1899 and lasted for a few years. Magnetic concentration was employed, but at that time the process was not well developed and difficulties were encountered with the pyrrhotite which accompanies the magnetite. The deposit has been explored for a distance of 2500 feet on the strike and is opened by a tunnel 1400 feet at an average depth of 135 feet from the outcrop. The width of the stopes ranges from 50 or 60 feet to 100 feet or a little more. The ore is not sharply defined along the walls in most places, but shades off into the country through a gradual decrease in magnetite, the gangue being of the same mineral nature as the inclosing rock. The latter has the composition of augite syenite and closely resembles the ore bearing syenite gneisses of the Adirondacks. In 1912 plans were under consideration for reopening the mine; it was proposed to erect a mill of 1500 tons daily capacity, using the wet magnetic method of concentration and roasting the concentrates to free them of sulphur. Experimental tests with the process indicated a product could be made with an average of 64 per cent iron, after crushing through 20 mesh screens, with a phosphorus content of .03 per cent and sulphur .3. Foundations were laid for the mill, but the plant was not completed.

3 Hematites of St Lawrence and Jefferson Counties

Hematite, both soft and hard, is found in quantity in the Precambrian of St Lawrence and Jefferson counties, on the outskirts of the main Adirondack Precambrian area. On this side the Precambrian reaches out from the highland into the St Lawrence valley and even extends across the latter into Canada. The hematite is associated more particularly with the sedimentary portion of the series, which is classed with the Grenville, and which is distributed in long belts running northeast-southwest. The wall rocks are usually rusty gneisses or schists, the same beds that contain the pyrite ores, but occasionally they are bordered on one or both sides by limestone. In a few places the bodies have a capping of Potsdam sandstone which rests in horizontal layers upon the highly inclined Precambrian strata, but as a rule they are covered only by soil and earth.



The main hematite mines of St Lawrence-Jefferson counties

The ore bodies occur as seams following the schistosity of the gneiss and as irregular impregnations of the latter. They are apparently replacements of the country rocks formed by invading ferruginous solutions. Smyth connects the source of the iron with the pyrite which appears very probably from the close association and the further fact that the hematite was deposited at a much later period, probably largely in Postcambrian time, since the Potsdam in contact with the ore is itself heavily impregnated and altered so as to be difficultly distinguished from the normal ore.

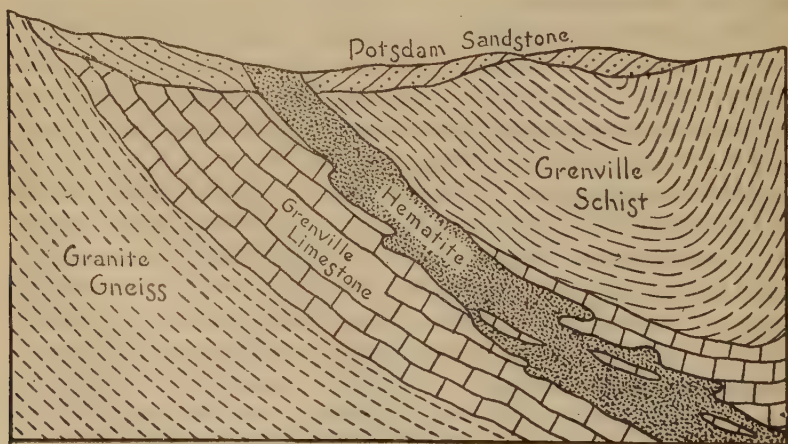
The occurrences are individually quite widely distributed and there are a large number of mines and prospects within the area covered by the towns of Antwerp and Theresa, Jefferson county, and Gouverneur, Rossie, Hammond, Macomb, Fowler, Edwards, Hermon, De Kalb and Canton, St Lawrence county. Most of them may be grouped in a few belts that have the same boundaries as the pyrite belts. The more important occurrences from a mining standpoint are found in the gneiss belt which extends from the town of Philadelphia on the southwest into and across southern St Lawrence county and includes the Antwerp-Keene deposits which have been most extensively exploited.

The hematites assay upward of 40 per cent iron, the richest averaging 55 to 58 per cent, and a variable phosphorus content, too high for Bessemer ore. The main drawback seems to be a rather high percentage of silica, arising from unreplaced quartz and silicates of the gneiss and their alteration products. The total product has been about 2,500,000 tons. Mining was in progress from about 1825 to 1910. In the early years the ore was smelted locally in charcoal furnaces, but during the last 30 years or so it was shipped mainly to Pennsylvania.

Little systematic exploration has been attempted in this section; in fact there is less known about the resources than of any other iron ore district in the State. Most of the deposits, so far opened, were exposed at the surface or showed indications of their presence by the character of the soil which usually takes on a deep iron stain wherever in contact with the hematite below. The cover of drift on the uplands is thin, a few feet of sand and gravel with some boulder clay constituting the glacial deposit in most places. There is no doubt that deposits are concealed under the Potsdam strata, through which the iron is not readily revealed, and others may lie under drift-filled valleys in which the glacial accumulation may have a thickness of 100 feet or more. A guide to exploration is to be found in the occurrence of pyrite which accompanies the hematite belts throughout their extent. In the Antwerp-Keene belt there seems

to be a promising field for exploration southwest of the Caledonia mine, along the contact of the limestone and schist which is mainly hidden by a thin cover of sandstone and has not been actually tested in the immediate neighborhood of the Caledonia mine itself. It is along the contact that the iron-bearing solutions would find the easiest channels for their circulation and the limestone being readily soluble would seem to offer the most available ground for the accumulation of considerable bodies of hematite.

Caledonia mine. This has been one of the main producers in the district and was last worked in 1907 by the Rossie Iron Ore Co. Its output exceeded 500,000 tons. The ore is soft hematite with 50 per cent or more of iron, and has a relatively high proportion of lime which is beneficial to its smelting qualities. Actual analyses of ore shipments show 52 to 58 per cent iron, 7 to 8 per cent lime, and .5 per cent phosphorus. The deposit lies near the contact of the Grenville pyritic gneisses and crystalline limestone, and the ore is encountered in both. It is capped in part by Potsdam which rests on an uneven erosional surface of the crystallines. The gneiss in this place is a quartz schistose phase, carrying graphite and pyrite, more or less altered secondarily to chlorite and serpentinous products, as an accompaniment likely of the ore-forming process. The foot wall which is followed in the main shaft consists of limestone, while the schist is seen on the surface to the east and also is encountered underground in the hanging and as horses within the ore. The limestone along the contact with the deposit is uneven and contains pockets and irregular cavities filled with hematite. The hematite not infrequently bears marks of replacement in its simulation of the banding and structural character of the gneiss.



Occurrence of hematite in the Caledonia mine, St Lawrence county

Old Sterling mine. In tracing the hematite belt southwest of the Caledonia mine, the next outcrops and pits are found at Keene's station where there are several showings that have been exploited more or less. The Keene mine is the principal one; lying 1 mile in a direct line from the Caledonia shaft. The workings are inaccessible but are said to be extensive, reaching a depth of 400 feet. Pyrite is found in close association with the hematite. The Morgan or Pardee mine is next in order, $1\frac{1}{4}$ mile farther southwest and about 1 mile from the Old Sterling. It consists of a large open pit, on the western edge of the gneiss belt, partially sunk through Potsdam sandstone. Pyrite shows in the hanging side.

The Old Sterling mine consists of an open pit, 500 by 200 feet across, said to be 115 feet deep, with underground workings to the south and southwest of it for a distance of 900 feet and reaching a depth of about 200 feet from which the ore was obtained in later years. The ore is a soft earthy hematite, with some of the hard compact specular variety, and is more or less intermixed with secondary silicates of chloritic character (locally called serpentine) that had to be sorted out. Some of the soft ore was used for paint. Potsdam sandstone overlies the ore on the west side of the pit and its contact is scarcely distinguishable owing to the alteration that has taken place in the lower beds. The ore is somewhat silicious and carries from 40 to 55 per cent iron, with about .1 per cent phosphorus. The output is estimated at over 750,000 tons. The last operations were in the period 1904-10.

Dickson mine. The southwestern end of the Keene-Antwerp ore belt includes the Dickson property which was worked first in 1858 and for the few years following 1905. The occurrence is very similar to that at Old Sterling 1 mile northeast, the ore being earthy hematite as replacement of a graphitic gneiss or schist, following one or more seams of the latter. The mine was opened by an incline which in 1906 had reached a depth of 160 feet on the dip which was steep to the northwest. The thickness varied from 10 to 40 feet.

Shirliff mine. One of the principal producers of ore in the past has been this property in the town of Philadelphia, Jefferson county. It lies to the west of the axis of the Keene-Antwerp belt. It was worked up to 1880 or a little later, but is stated by Smock to have been exhausted by 1888, when his report was written. The ore was exploited by an open cut 1300 feet long and for a farther distance of 500 feet underground, while the workings reached a depth of 200 feet or more.

4 *The Clinton Hematites of Central and Western New York*

The Clinton ores are discussed in a special bulletin of the State Museum,¹ from which the following brief notes are mainly taken. The Clinton formation comprises an assemblage of shales and limestones mainly, with which one or more seams of hematite is commonly associated. The iron ore is not universally present, but occurs quite generally in the portion of the outcrop between Herkimer and Monroe counties, a distance of 120 miles, about two-thirds of the entire length of the belt.

The Clinton hematite has a characteristic habit, being a "fossil" ore, so-called; in most examples fragments of fossil organisms are discernible, originally of calcareous nature, but now partially or completely replaced by the iron oxide. The extent to which the process of replacement has taken place varies considerably, and with it the grade of the ore which ranges from around 20 per cent to about 45 per cent iron. This fossil ore has a calcareous base. In the eastern section of the outcrop, included by Oneida and Oswego counties, an oölitic bed is usually encountered. This ore differs remarkably from the normal phase, having a granular texture which arises from the occurrence of the iron oxide in the form of small round particles, that are cemented into a solid mass by the same material. The particles usually have a central core of quartz, and the oölitic ore has thus a siliceous rather than calcareous gangue.

From a mining standpoint the ore belt includes four areas that have present or prospective importance by reason of the presence of ore-seams of commercial grade. The first of these in regard to actual output is the area centering about Clinton, Oneida county, extending about 10 miles east and west, with two seams — an upper of fossil nature 6 feet thick but low grade and a lower oölitic bed 20 to 36 inches thick containing 40 per cent or more of iron on the average. The oölitic bed is in some places split into seams by a shale parting, but there is no ground for assuming the existence of two distinct layers of this ore as is sometimes done. The Clinton mines altogether have yielded about 2,000,000 tons. The second area of potential importance lies at the west end of Oneida lake, where an oölitic bed was shown by a test drilling, but has not been exploited or even satisfactorily explored as yet. The third area is encountered in northern Cayuga county, beginning near Sterling Station and reaching west as far at least as Wolcott, Wayne county. The excavations and drill tests about Sterling Station show 30 to 36 inches of fossil ore in a single seam. At Wolcott two layers, 12 and

¹ Iron Ores of the Clinton Formation in New York State, Bul. 123, 1908.

MAP SHOWING
POSITION AND EXTENT
OF THE
OUTCROP OF THE
CLINTON FORMATION
IN
NEW YORK



21 inches thick respectively, are present. In the town of Ontario, Wayne county, is the fourth area, with a bed of fossil ore 18 to 36 inches thick. This part has been worked by surface stripping for a distance of 5 or 6 miles along the outcrop and explored for several miles additional.

In their entirety the Clinton ores constitute the most considerable ore reserve that is known to exist in the State. It is estimated on a conservative basis that approximately 600,000,000 tons of the ore exist in the three principal areas already opened in ore seams at least 18 inches thick and under less than 500 feet of cover.

The Clinton hematites average about 40 per cent iron, taking the heavier seams only into account. The oölitic member in Oneida county gave an average return in one of the mines of 40.27 per cent; while separate analyses showed from 30 to 56 per cent. The fossil ore of the western section contains from 35 to 45 per cent iron as an average. Phosphorus is relatively high in most of the seams, ranging from .25 to 1 per cent, or from 1 to 2 per cent reckoned on the basis of metallic iron. It is thus mainly serviceable for foundry iron, which was formerly made in local furnaces at Kirkland, Franklin Iron Works and other places along the belt.

Borst mines. The principal mine operations in the eastern section in recent years have been carried on at Clinton by C. A. Borst. The output has been used in part for grinding into paint, for which the Clinton ore is excellently adapted, but the greater share has been sold to iron furnaces in Pennsylvania. The mines are worked underground by the long-wall method, the entry being from the west and the face of ore being worked along the dip so as to provide natural drainage and also a favorable grade for tramming. The ore is inclosed by shale of which about 2 feet is blasted down from the roof to give working room. The mine equipment is complete and modern in type. The seam worked is about 30 inches thick and returns 40 to 45 per cent iron.

The mines formerly operated by the Franklin Iron Manufacturing Co. are also at Clinton. They were mainly worked in the period after 1880 and up to 1907. The mine lay-out and ore conditions are similar to those at the Borst mines.

East and west of Clinton are a number of old open-cut mines once used to supply ore for the Kirkland, Franklin Iron Works and Taberg furnaces.

Fair Haven mines. At Sterling Station, Cayuga county, the Fair Haven Iron Co. conducted operations a few years ago by steam shovel methods, stripping 10 to 25 feet of soil and shale which overlies

a seam of fossil hematite 30 to 38 inches thick. The ore is reported to have averaged 36 to 38 per cent iron. Above the main seam is a 4-inch seam of hematite and one or more thin limestone layers.

West of this property are open cut mines worked in 1887 and 1888 by the Furnaceville Iron Co.

Ontario mines. The town of Ontario, Wayne county, has yielded most of the ore output from the western Clinton belt. The workings extend almost continuously across the whole width of the township and for one-fourth of a mile and more back from the outcrop. The bed continues east into the adjoining town of Williamson for at least 2 miles but has not been mined in that part. The line of workings lies 3 miles south of Lake Ontario and $\frac{1}{2}$ mile north of the Rome, Watertown and Ogdensburg branch of the New York Central lines. The ore is the fossil type and averages 20 inches thick. The Furnaceville Iron Co., the Ontario Iron Co. and the Wayne Iron Ore Co. have been engaged in mining here in recent years by the open cut method. The ore is stripped in longitudinal stretches, the width of which is determined by the operating radius of the shovel, usually about 45 feet. The débris from the overburden is spoiled to the north of the cut from which the ore was removed in the previous operation. When the bench has been exposed it is loosened by blasting and then loaded by a smaller shovel into cars for shipment.

5 *Limonites of Dutchess and Columbia Counties*

The limonite deposits of Dutchess and Columbia counties are a part of a long series of similar deposits that extend from Vermont through Massachusetts, Connecticut, New York and south to Alabama along the main Appalachian uplift. They occur in the belt of metamorphosed Paleozoic sediments which lies to the west of the Precambrian crystalline belt represented in New York State by the Hudson Highlands.

There are two principal groups of deposits; the one running northeast from Fishkill in the valley of Fishkill creek, Dutchess county, and the other farther east following the north-south valley traversed by the Harlem Railroad from the Highlands in Dutchess county to Hillsdale, Columbia county. The latter group is the more important. The geologic formations within the vicinity comprise Precambrian gneisses and stratified quartzites, limestones and schists. The quartzites lie immediately on the gneiss and have been assigned to the Lower Cambrian; the limestones and schists above are supposed to range from Cambrian to Ordovician in age.

According to Smock, who visited many of the mine localities when operations were in progress and thus had advantages for observation not now obtainable, the ore occurs in limestones or along the contact of limestone and schist, or it lies wholly within the latter; as a rule the contact affords the most favorable locus for the ore occurrence. The limonite occurs in small irregular pockets as well as large bodies and is accompanied by ochreous clay.

Some carbonate is found in the workings, intermixed with the limonite or forming independent bodies or horizons within the latter. It is the principal ore in one or two of the mines, notably in the Morgan, south of Halstead station, Columbia county, and can be seen in large bodies in the Amenia mine although here the ore is mostly limonite. The carbonate often has a brownish coating of oxide, so that its existence may not be inferred at first glance. It has been suggested by several writers that the carbonate constitutes the original ore from which the limonite has been derived by oxidation and hydration under surface conditions; this view is probably correct in the main, although it is not unlikely that some of the limonite has been formed directly by the weathering of pyrite that occurs rather freely in the schists. There is some question about the method of accumulation of the carbonate; Dana and others have considered the siderite to lie in interbedded seams with the limestone and schists, which if true would mean that the deposits are continuous with the wall rocks; on the other hand, the explanation that the iron has been introduced in solution and as a replacement of the limestone seems more in conformity with the present known facts of the field occurrence.

The more important mines of the district lie within or close to the limestone valley that borders the high ridges of the Berkshires on the west and extends north and south along the New York and Massachusetts-Connecticut state line. The valley is narrow and broken in places by minor ridges of schist which rise on the west side into a series of prominences somewhat less rugged than those on the east side. This valley is followed by the Harlem Railroad (New York Central lines) and most of the mines are close by. The list of the larger productive properties includes the Dover, Amenia, Manhattan, Maltby, Mt Riga, Dakin and Kelly mines in Dutchess county and farther north the Morgan, Reynolds, Weed, Copake, Hillsdale, Mitchell and Haight mines in Columbia county. In the Fishkill-Clove valley are the Shenandoah, Sylvan Lake, Pawling, Beekman and Clove mines, all in Dutchess county.

The mines are mainly open pits, but drifts may be run from the sides or bottom along the course of the ore and mining carried on partly underground. The stripping varies from a few feet to over 100 feet. In the deeper bodies it would appear that underground



The southeastern limonite district (after Putnam)

work with caving might be introduced and would be more economical than stripping so much cover. A few mines were worked through vertical shafts. The abandoned open pits are now filled with water to

within a few feet of the surface; some are 500 to 600 feet long and 100 to 200 feet wide. As much as 200,000 tons of ore have been mined from a single pit within 150 feet of the surface. Few, if any, of the deposits were exhausted by the previous operations; the production of ore became unprofitable with the loss of the local markets supplied by the Poughkeepsie and other nearby furnaces and through competition with the Lake Superior ores. The active period of exploitation may be said to have ended about 1893.

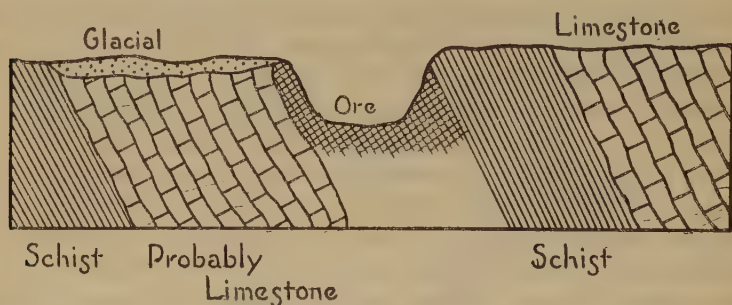
The ores occur in coherent masses and in earthy condition, the former called "rock ore" which is sorted by hand and the latter "wash ore" being the residue obtained after the removal of the clay and sand by washing. The masses occur in spheroidal, stalactitic and irregular shapes. The iron content of the shipping product ranges from 40 to 50 per cent and the phosphorus below .5 per cent and occasionally below the Bessemer limit. The sulphur content is low.

There is little doubt that in the course of time the ores will again be in request. Some of the more accessible properties possibly could be worked under present conditions.

In the western part of Columbia county, a short distance from the Hudson river there is a small district that has produced carbonate ores. The deposits lie along the western slope of a range of hills that begins just south of the city of Hudson. They are included between slates and quartzites and show some points of similarity to the limonites above described. The Burden mines are the largest in the district, they were worked between 1875 and 1901. The ore is a gray compact siderite containing some calcite, quartz and pyrite. The silica percentage is apt to be rather high, and it is necessary to subject the ores to a roast to remove the sulphur and increase the iron. The greater part of the mined product was of Bessemer character. The production of limonite in southeastern New York ceased practically in 1905, since which time the industry has been dormant except for an occasional shipment.

Amenia mines. One of the larger mine workings in the limonite district is at *Amenia* in a small north-south notch in the ridge just west of the village. There are three pits, the Gridley, Palmer and Weed, but all are opened on the same body of ore and together form a continuous trench one-half of a mile long. The deposit lies along the contact of a fissile micaceous schist which can be seen on the east side of the workings at the north end, and white crystalline limestone which is now concealed but is said to have been exposed in the bottom of the pits and on the west wall of the Palmer pit.

The strata have a dip of 60° to 70° to the east and trend a little east of north. The ore probably makes under the schist to the east but has not been followed far in that direction on account of the heavy overburden. The pit in places is 300 feet across.



Cross-section of the Ameniam limonite mine (after Putnam)

The ore is in part of soft ochreous character and partly consists of hard lumps and hollow spherical masses ("bombs"). Bodies of carbonate (locally called "white horse") have been left in the workings, apparently on account of its lower iron content. Some of the carbonate was mined and used in the furnace at Wassaic. The washed limonite is reported to have carried 44 to 51 per cent iron and phosphorus up to .4 or .5 per cent.

The Palmer and Weed pits at the north are called the Ameniam mine which has been worked more extensively than the Gridley mine and has shipped some ore in recent years. Smock credits the Ameniam mine with an output of 200,000 tons in the period of 20 years preceding 1889. There is a washing and pumping plant on the property.

Manhattan mine. The Manhattan mine is situated at Sharon station, just west of the tracks of the Harlem Railroad. The output at one time was shipped to the furnaces of the Manhattan Iron Works in New York City, long since dismantled. In the early eighties it was worked by the Sharon Bessemer Ore and Iron Co. who ceased operations in 1888; since then the property has been idle. The pit is now filled with water, forming a pond 500 feet in diameter. The ore is covered by a variable amount of drift which thickens to the south and lies upon limestone. At the south end of the pit as much as 160 feet of stripping has been removed, but to the south and near the highway the ore comes to within 40 feet of the surface. The cover increases also to the east where the ore extends on the dip of the limestone and under the schist which has

been encountered in drill holes recently put down by the Ramapo Ore Co. It appears that the main ore body follows the contact of the two formations which have a northeasterly strike and a southeasterly dip of 30° or a little more.

The ore of this mine is lower in phosphorus than the usual run of the limonites. Analyses of the washed ore shows 47 to 50 per cent iron and .04 to .09 per cent phosphorus.

Maltby mine. This large open pit is $1\frac{1}{2}$ miles northeast of Millerton and almost on the Connecticut line, within sight of the famous Orehill mines which lie across the border to the southeast. The Central New England Railroad adjoins the property on the west. The mine was last worked by the Thomas Iron Co. which ceased work in 1891, but previously had been operated by C. S. Maltby and the ore smelted in a furnace at the mine. The pit is about 600 feet long northeast and southwest and 400 feet wide. The ore apparently lies between limestone which shows on the southeast side and the schist, although the latter does not appear in outcrop. There are three bands of ore exposed on the southeast wall, two of which are narrow and inclosed within limestone and a thicker band of 50 or 60 feet lying on limestone and covered by drift. The limestone dips 45° or so to the northeast. W. H. Hobbs (see references at end of chapter) has given a section of the formations which indicate that the ore is repeated by faulting, although the evidence on this matter is not very clear.

Analyses of the ore are reported by Putnam who found the washed limonite to contain 41 per cent iron and .156 phosphorus, and the lump or rock ore 48 per cent iron and .215 phosphorus. The mine is reported to have been opened in 1750. Its output is not recorded.

Mt Riga mine. The Mt Riga mine is an open pit 500 feet long and 100 to 200 feet wide, one-half of a mile southeast of Mt Riga station on the Harlem Railroad. The last work on the mine was performed by Barnum, Richardson & Co. about 1888; previously operations had been carried on by the Mt Riga Iron & Mining Co. which stopped work in February 1885. The present owner of the property is George E. Kaye of Mt Riga. There are few details available about the mine which is now filled with water, but it would appear that the ore rested on limestone and was capped by drift which is 50 feet thick on the south end of the pit. Putnam reports that the average stripping was 15 feet and that the yield of washed ore was one-half the mined product. A sample from 500 tons of washed ore returned 41.6 per cent iron and .61 phosphorus.

The ore body continues to the south beyond the pit and onto the property of Mrs C. B. Miller where some ore was taken out through shafts, one of which is across the highway to the southeast of the pit.

Between Boston Corners and Mt Riga at the foot of the high ridge which lies along the state line are the Kelly and Dakin mines, of which few particulars are to be had. The Dakin is a little north of Mt Riga and the Kelly still farther distant.

Weed mine. The Weed mine has been recently under operation by Barnum, Richardson & Co. for supply of their furnaces at Limerock, Conn. The mine is equipped with a new hoist and washing plant. The property is $1\frac{1}{2}$ miles north of Boston Corners, between the Harlem Railroad and the Central New England Railroad. The ore is opened by a long trench and followed underground on the easterly dip which carries it below the schist hanging wall. The foot wall is of the same schist, but of less weathered character. The dip is about 35° . The mine had yielded 168,000 tons up to the time of Putnam's report for the tenth census. An analysis reported by Smock shows 43 per cent iron and .11 phosphorus.

Copake mines. These are at Copake Iron Works on both sides of the Harlem Railroad. There are two openings to the west of the tracks which represent the earlier operations while the larger and more recently worked mine is northeast of the station. The latter is a pit 500 feet long and up to 200 feet wide opened in glacial materials, except at the northeast end where a bluish white limestone appears showing a dip of 25° or so to the east. The ore appears to lie in a depression of the limestone and apparently near the top of the beds, as the schist may be seen nearly on a line with the pit to the north. The contact between the two formations is approximately indicated by the brook which flows south by the pit. There are small openings just north of the main pit and prospects with indications of ore for some distance farther north. The mine was closed about 1888. It was operated in connection with the Copake furnace both owned at present by John Mills, Twin Lakes, Conn.

There is more or less carbonate intermixed with the limonite, and in one of the prospects on the north end it is practically the only ore. Putnam reports that a sample of washed and lump limonite combined returned 46.8 iron and .424 phosphorus. A sample of the carbonate contained 30.8 iron and .248 phosphorus.

6. *The Staten Island Limonites*

The limonites of Staten island supply an interesting example of ore occurrence, but are no longer of commercial importance. In character and probably in genesis they are closely parallel to the limonite ores of eastern Cuba which have recently come into prominence; their restricted distribution, however, excludes them from consideration as a basis for present day mining. They are found on the serpentine ridge which constitutes the backbone of the island, the higher ground between St George on the north shore and Richmond in the central part. The serpentine represents the altered product of a basic intrusive of the peridotite class of rocks. Little of the original silicates is now left, although occasionally particles of pyroxene and olivine bear witness to the original character of the mass, as does also the chromite which is distributed in small grains all through the serpentine. The ore lies in depressions upon the serpentine and is covered by clays and sand: a small percentage of chromium is present, according to the published analyses which show 38-55 per cent iron; also cobalt and nickel. The old mine localities are about 1 mile north of New Dorp station (New Dorp mine) at the Four Corners on the Richmond turnpike (Tyson's mine) and on the Ocean Terrace road (Cooper & Hewitt mine). A detailed account of the occurrences is found in Putnam's article in the Tenth Census reports. The ore yield is placed at 250,000 tons. Mining terminated about 1880.

References

- Beck, Lewis C. Mineralogy of New York, 1842
 Eckel, Edwin C. Limonite Deposits of Eastern New York and Western New England. U. S. Geol. Surv. Bul. 260, 1905, p. 335-42
 Emmons, Ebenezer. Geology of New York. Report on the 2d Dist., 1842
 Hall, James. Geology of New York. Report on the 4th Dist., 1843
 Kemp, J. F. The Geology of the Magnetites near Port Henry, N. Y., and especially those of Mineville. Amer. Inst. Min. Eng. Trans., v. 27, 1897
 ——— Titaniferous Iron Ores of the Adirondacks. U. S. Geol. Sur. 19th Ann. Rep't, pt 3, 1899
 ——— Geology of the Elizabethtown and Port Henry Quadrangles. N. Y. State Mus. Bul. 138, 1910
 Koeberlin, F. R. The Brewster Iron Bearing District of New York. Economic Geol., v. 4, 1909
 Nason, F. L. Notes on Some of the Iron Bearing Rocks of the Adirondack Mountains. Amer. Geol., v. 12, 1893
 Newland, D. H. Geology of the Adirondack Magnetic Iron Ores, with a Report on the Mineville-Port Henry Group, by J. F. Kemp. N. Y. State Mus. Bul. 119, 1908

- Newland, D. H.** On the Associations and Origin of the Nontitaniferous Magnetites in the Adirondack Region. *Economic Geol.*, v. 2, 1907
- & **Hartnagel, C. A.** Iron Ores of the Clinton Formation in New York State. *N. Y. State Mus. Bul.* 123, 1908
- Putnam, B. F.** Notes on Samples of Iron Ores Collected in New York. *Reports of the Tenth Census*, v. 5, 1886
- Smock, J. C.** First Report on the Iron Mines and Iron Ore Districts in the State of New York. *N. Y. State Mus. Bul.* 7, 1889
- Smyth, C. H. jr** Report on the Geology of Four Townships in St Lawrence and Jefferson Counties. *N. Y. State Mus. 47th Ann. Rep't*, 1891
- On the Clinton Iron Ore. *Amer. Jour. Sci.*, v. 43, 1892
- Wendt, A. F.** The Iron Mines of Putnam County, New York. *Amer. Inst. Min. Eng. Trans.*, v. 13, 1884

LEAD

Galena, the principal ore of lead, is associated to some extent with the zinc ores in the Edwards district and also with the zinc deposits in the Shawangunk region. A description of the occurrences in these two districts will be found under zinc. Lead alone, or with minor amounts of zinc, was once mined in the western part of St Lawrence county, notably in the towns of Rossie and Macomb, also in the town of Alexandria, Jefferson county; in the town of Ancram, Columbia county; town of Northeast, Dutchess county; and in a few other places.

At the time of the First Geological Survey of New York State 1836-40, much interest was manifested in the deposits in the towns of Rossie and Macomb. A very full account of the lead occurrences and of the mining operations is given in the report by Professor Emmons on the Third District. The Coal Hill and Victoria veins are particularly mentioned by Professor Emmons as having been the basis of rather active exploration in the early days.

The Coal Hill vein was worked by two companies, the eastern section having been under operation by the Rossie Lead Mining Co. and the western section by the Rossie Galena Co. According to the local records mining at this locality began about 1836 and the output of ore was smelted at a furnace on Indian river, about 1 mile distant from the mines. The product of the two companies up to the time they ceased operations was 3,250,690 pounds of metallic lead. The average content of the furnace ore is said to have been 67 per cent. It appears that in 1852 operations were again revived by the Great Northern Lead Co. which employed a number of practical miners from Cornwall, England, and work was extensively prosecuted for about 2 or 3 years. Later the mines and works were leased by J. B. Morgan who operated them for a time. In 1868 the plant was finally closed and has remained idle

since. The Coal Hill vein outcrops on the face and top of a flat knob of gneiss and occupies a vertical fissure from 2 to 6 feet wide within a parallel zone of brecciated rock. The strike is north 80° west. The galena occurs in disseminated particles and in larger masses within calcite gangue. The lead ore is accompanied by minor amounts of chalcopyrite, sphalerite and pyrite and a little fluorite. The wall rock consists of a gray gneiss which has been intruded by red granite.

The Victoria mine, also known as the Pardee mine, lies $1\frac{1}{2}$ miles south of Rossie and about 1 mile northeast of the Coal Hill mine. Its situation is similar, the vein being exposed along the side and dip of a low ridge of grayish, more or less granitized gneiss. The strike is a little north of west and the dip approximately vertical. It was opened about the same time as the Coal Hill property. A vertical shaft was put down at the base of the hill reaching a reported depth of 300 feet and other shafts were sunk on top of the ridge. The vein ranges from 2 to 4 feet in width and is composed of calcite carrying some galena and minor amounts of sphalerite, chalcopyrite, pyrite and green fluorite. Considerable brecciation has occurred along the fissure and stringers of the material make off into walls for short distances. The country rock on the outcrop of the vein is an injected gneiss but it would appear likely that limestone was encountered in depth since there are large blocks of this material on the spoil bank. A separating works and smelter were erected on the property to treat the ore of the mine. The output of metallic lead is not known.

Another place where mining for lead was carried on in the middle years of the last century is at Mineral Point on Black lake, town of Macomb. The deposit is said to have been discovered about 1836 and 3 years later a company known as the Mineral Point Lead Manufacturing Co. was organized to work the deposit. Very little is known about the outcome of these early operations. In the sixties of the last century the property was leased by J. B. Morgan who also for a time operated the Coal Hill property. The occurrence is very similar in its features to the deposits in Rossie, the vein occurring in gneiss and consisting of a small fissure filled with calcite and carrying sulphides of lead, copper and iron.

Another galena vein occurs on the farm of F. E. Turner, some three miles north of Brasie Corners, town of Macomb. It measures up to 2 or 3 feet in width and can be followed for 100 feet or more along the edge of a limestone ridge. In places it carries abundant galena with minor amounts of sphalerite and would be workable

if the ore were obtainable in larger quantity. The deposit was operated in a small way 10 years ago by H. D. Tann of Pierces Corners.

About one-half of a mile south of Pierces Corners or Macomb a lead vein occurs on the Downing farm where operations were carried on in a small way about 12 years ago. There is a shaft 25 or 30 feet deep. It was operated by J. H. Donovan.

About 1 mile south of Pierces Corners is an occurrence of lead on the Pennock farm. The developments consist of two vertical shafts about 200 feet apart located on a fractured zone which strikes about north 70° west and measures about 15 feet wide. The westerly shaft is said to be 150 feet deep. Near the eastern shaft there is an open cut of 15 feet into the hill in which the shaft has been sunk and from this a considerable quantity of ore was taken a few years ago, although the main operations were carried on by J. B. Morgan in the middle of the last century. The stack of an old furnace still stands on the property.

Lead also occurs on the Jones farm about 1 mile southeast of Pierces Corners, where some prospecting was carried on about 10 years ago.

An interesting occurrence of galena is found about three-quarters of a mile north of the village of Redwood, town of Alexandria, Jefferson county. It is exposed on the sides of a low cut along the railroad north of the Redwood station. The outcrop of the vein is in Potsdam sandstone which forms a knob with an exposed thickness of from 35 to 40 feet. The sandstone along the sides of the vein is much fractured and shows vertical joining. The main vein is about 4 feet wide and contains 2 feet of solid calcite in the middle with a foot or so of brecciated sandstone cemented by calcite on either side. The strike is north 55° west. The vein can be traced from the railroad cut to the southeast across the adjoining field to a little ravine and west of the cut for about 200 feet over the top of the hill. It has been opened in several places but the date of the operations are not known. The vein does not carry any large amount of galena. It is apparent from the field relations that the sandstone overlies Grenville limestone as the latter is exposed in considerable force just north of the sandstone knob. The limestone itself is characterized by a small amount of galena in disseminated grains and crystals.

Galena was mined at one time in the town of Ancram, Columbia county, at the locality known as the Ancram Lead Mines, a station on the Central New England Railroad between Boston Corners and

Pine Plains. The deposit is reported to consist of 2 or 3 small veins which lie along the contact of limestone and schist. The ore is rather lean, carrying small amounts of galena with some chalcopryrite, sphalerite and occasional barite, in a gangue of calcite and quartz. The property has been explored on an extensive scale, as evidenced by the shafts and underground workings and the large accumulation of waste, but the operations were never profitable. The galena contains a little silver.

Additional occurrences of galena have been recorded in various parts of the State. Near Smithfield, town of Northeast, Dutchess county, is a small vein that has produced some ore; it is reported to have been worked as early as 1740 and the ore shipped to Bristol, England, and again during the Revolutionary War, when a few tons of lead were produced. Another locality is Ossining, Westchester county, where galena occurs with other lead minerals in dolomitic limestone. At White Creek, Washington county, it is found in small stringers in slate. In Montgomery county, $1\frac{1}{2}$ miles south of Sprakers Basin, veins of galena associated with sphalerite and pyrite are found in shale. Other localities are Schoharie, Schoharie county; Martinsburg, Lewis county; towns of Vernon and Westmoreland, Oneida county; and near Rochester, Monroe county.

References

- Beck, Lewis C. Mineralogy of New York, 1842
 Emmons, Ebenezer. Geology of New York. Report on the 2d Dist., 1842
 Mather, W. W. Geology of New York, Report on 1st Dist., 1843
 Smyth, C. H. jr The Rossie Lead Veins. School of Mines Quarterly, July 1903
 Whitlock, H. P. Minerals not Commercially Important. N. Y. State Geol. 23d Ann. Rep't, 1904

MANGANESE ORE

The manganese compounds that serve as ores of manganese have only a very restricted representation in the State. The two commoner minerals are pyrolusite, the dioxide, and psilomelane, the hydrous oxide. The latter contains usually more or less iron and grades into an impure earthy substance called wad. There are no considerable deposits of pyrolusite anywhere in the State; in fact it may be said that there are no deposits in which the mineral is found by itself, and only such minor quantities as may be present in the superficial coatings of pyrolusite on other minerals. Psilomelane is found in greater abundance but of a low grade of quality.

W. W. Mather in his reports on the First Geological Survey of

New York gives an account of the occurrence of wad in Columbia and Dutchess counties which it appears was the source of some commercial ore during the middle part of the last century. Recently the deposits were relocated and explored by Professor Nelson C. Dale, who has prepared a paper¹ on the occurrences for publication by the State Museum. The following abridged account is based on information given by Professor Dale in the paper mentioned.

The ore occurs in a district that extends some 25 miles north and south and lies mainly within the towns of Canaan, Hillsdale and Ancram, Columbia county. It comprises an area altogether of 125 or 150 square miles in the western foothills of the Taconic range. The manganese is distributed within certain swamps or marshes which occupy small depressions in saddles or divides between the hills or in terrace-like benches at the foot of the prominences, usually at an elevation of 1200 to 1400 feet above sea level. These bogs serve as catchment basins for the drainage from the higher ground and discharge into the Hudson river. The area is largely underlaid by slates and schists of Ordovician age.

The bog manganese is found as nodules and nodular aggregates sometimes cemented into a more or less firm mass, inclosed in a matrix of whitish clay. It is thought that the manganese is derived by leaching of the small amounts present in the country rocks and is carried into the bogs as soluble bicarbonate where its precipitation takes place through oxidation or as the result of reaction with calcium bicarbonate. A characteristic section through one of the bog deposits shows at the top 12 inches of brownish clayey loam with nodules and nodular aggregates of wad, then 28 inches of hardpan with occasional boulders and rock fragments cemented by manganese, and at the base consolidated hardpan carrying no manganese. An analysis of several samples from different localities indicated about 22 per cent of manganese as a maximum.

One of the localities where the ore was worked in the early days is the Gott-Mesick bog in Spencertown, Columbia county. In the town of Hillsdale are the bogs on the Palmer farm and the Joseph Goodsell farm. Other localities where the ore occurs are the David Parson farm (now owned by Mr Beaver) about $1\frac{1}{4}$ miles west of Flatbrook and the R. H. Girdler farm 1 mile south of Canaan Center. Tests carried out by Professor Dale indicated that the available supplies in the different occurrences were limited to a few hundred tons at most.

¹ Postglacial Manganese in Columbia county, N. Y., N. Y. State Mus. Bul. 207-208, 1919, p. 85-100.

References

- Beck, Lewis C. Mineralogy of New York, 1842
 Dale, Nelson C. Postglacial Manganese in Columbia county, N. Y. N. Y. State Mus. Bul. 207-208; 1919, p. 85-100
 Mathe, W. W. Geology of the First Geological District, 1843

MARL

Marl is an unconsolidated limestone. Its description seems to justify a separate article for the reason that it is quite independent of the hard limestones in areal distribution, has a different method of occurrence, and its physical properties do not permit the same extended uses to be made of the material as of limestone.

Chemically marl usually ranks with the high-calcium limestones. The proportion of lime carbonate is often well above 90 per cent, that is calculated on a water-free basis. When freshly dug it has a large moisture content, practically equal in weight to that of the marl itself; the water may be dispelled by prolonged drying in the air or more rapidly by exposure to the higher temperature of a kiln, since it is all mechanically held. Admixture with a little clay is common, also not infrequently with sand, so that small proportions of silica and alumina are usually shown by analysis. The magnesia content seldom exceeds 1 per cent.

The marls of New York are of recent and present day formation. They are found in surface depressions, associated with other unconsolidated materials and especially with peat, which often occurs on top of the marl. Swampy areas and shallow ponds and lakes frequently contain deposits. Whenever waters accumulate on the surface, the dissolved lime brought in by springs and streams may precipitate by evaporation and escape of the solvent carbon dioxide, a process that is facilitated by increasing warmth of the waters. The lime carbonate is also abstracted by shell organisms and by minute plant forms. In some instances the lime is deposited directly by springs and streams before the waters reach the collecting basin as tufa or travertine, which forms an incrustation on vegetable growth—mosses and grasses. Marls contain more or less shell remains of the organisms that abound in fresh waters and these may constitute a considerable proportion of the deposit, if not exceeding in amount the granular lime.

Occurrence. The more extensive marl deposits are in the central and western parts of the State. The large share which limestones have in the geological structure of that section contributes to their formation by supplying abundant calcareous material for solution

by ground waters. Moreover, the drift and soils of the region contain much lime in a comminuted and easily soluble condition.

Marl occurs in the marshy tracts south of Onedia lake, particularly in Cowaselon swamp which extends west from Canastota and is reported to contain several thousand acres of marl, covered in most places by peat. The deposit reaches a thickness of 30 feet. Many of the swamps and lakes of Onondaga county are underlaid with marl; this is very generally the case in Fabius, Tully, Camillus, De Witt, Manlius, Elbridge and Van Buren townships. Onondaga and Cross lakes have marl beds. Near Warners, west of Syracuse, the Empire Portland Cement Co. formerly worked a deposit for use in cement mixture; the marl bed averaged 6 to 7 feet thick and had blue clay underneath, which was employed with it. The American Portland Cement Co. also developed a marl deposit near Jordan to the west of the former locality. Both plants have been dismantled for some time.

The Montezuma marshes, which occupy a large area in Cayuga and Seneca counties, north of Cayuga lake, are in part underlaid with marl. A portland cement plant was established at Montezuma on the basis of the marl which there has a thickness of 14 feet.

In Wayne county the Cayuga marshes which cover a part of the town of Savannah contain a bed of shell marl 5-6 feet deep. Other deposits are found near Newark and in Cooper's swamp, town of Williamson.

Steuben county has numerous marl and tufa beds. Hall¹ mentions that they were employed for lime burning at Arkport and south of Dansville. In the town of Wayland beds of marl 2 to 14 feet thick formerly supported two portland cement plants, those of the Thomas Millen Co. and the Wayland Portland Cement Co.

In southern Monroe county a marl deposit occupies a part of the town of Wheatland and extends south into Livingston county. Tufa occurs at the top in many places and below is shell marl 3 to 4 feet thick. Another deposit occurs along Mill creek, underlying the marshes, and at Mumford it forms several beds.

In Livingston county the larger deposits are around Caledonia, just south of the Mumford locality. The Iroquois Portland Cement Co. built a large works near Caledonia to utilize marl, but the plant, like all of those designed for the same purpose, was unable to compete with the plants using hard limestone. The International Agricultural Corporation produces agricultural marl from the deposit at this place.

There are many marl swamps in Genesee county. An extensive

¹Geology of New York. Report on Fourth District, 1843, p. 484.

deposit occurs 1 mile west of Bergen. Around Leroy and Batavia several beds have been uncovered.

In Wyoming county the bottom of Silver lake is said to consist in part of marl.

In Chautauqua county Cassadaga lake and the bordering marshes contain marl. Both portland cement and lime have been made from the material, but these uses have long since been discontinued. Tufa and marl occur at the southern end of Chautauqua lake.

The following localities have been mentioned in different reports as having marl deposits, although little is known about the extent of the different beds. Along Tonawanda creek and near Lockport, Niagara county; Clarendon, Orleans county; near Lodi, Seneca county; Beaver Dams, Schuyler county; Cortland, Cortland county; Horseheads and Millport, Chemung county; Canajoharie, Fort Plain and Fonda, Montgomery county; town of Cherry Valley, Otsego county; 4 miles south of Kinderhook, Columbia county; town of New Baltimore, Greene county; and towns of Rhinebeck, Northeast, Amenia, Pine Plains, Stanford and Red Hook, Dutchess county. A deposit in Round pond near Sharon Station, Dutchess county, was worked a few years ago, and other occurrences in this section have been exploited at different times for the supply of aicultural lime.

Analyses of New York marls

	1	2	3	4	5	6	7	8	9	10
SiO ₂	6.22	.67	.26	.26	.42	1.10	.50	.49	2.10	.14
Al ₂ O ₃	1.70	1.07	.21	.10	1.08	1.50	2.00	.35	1.93	.36
Fe ₂ O ₃	.86	.13	.01							
CaO.....	47.86	54.53	50.98	52.86	52.36	54.54	52.70	52.71	48.78	53.16
Mgo.....	.04	.19	.19	.18	1.01	tr	1.09	tr	1.10	1.50
CO ₂	42.11	43.05	40.26	41.73	42.26	.....	42.61	.....	39.53	.....
Water, etc a....	2.20	.34	7.98	4.64	62.87	.....	.....	d	.....	.....
Total.....	100.99	99.98	99.89	99.77	100.00	.....	98.90	.....	.....	.....

a. Alkalies. b. Includes CaSO₄ 2.01 d CaSO₄ 3.48.

- 1 Montezuma, Cayuga county. Mineral Industry, v. 1, p. 52.
- 2 Caledonia, Livingston county (used by Iroquois Portland Cement Co.).
- 3 Warners, Onondaga county (used by Empire Portland Cement Co.).
- 4 Idem.
- 5 Wayland, Steuben county (used by Thomas Millen Co.).
- 6 Three miles east of Mumford, Monroe county. N. Y. State Mus. Bul. 44, p. 793.
- 7 Mumford, Monroe county, calcareous tufa, op. cit. p. 797.
- 8 One mile west of Bergen, Genesee county, op. cit. p. 785.
- 9 Canastota, Madison county, op. cit. p. 794.
- 10 Jordan, Onondaga county (used by American Portland Cement Co.).

Uses. Lime and portland cement may be made with marl in the place of hard limestones. The possibilities of utilizing the extensive deposits of the State for these purposes have received a good deal of attention, but no attempt along this line has proved commercially successful in the long run. The main drawback to such employment is the large proportion of dead weight that has to be reckoned with in the excavation and handling of the material. On this point the following statement from a paper by J. C. Russell¹ is of interest: "As has been determined by E. D. Campbell 1 cubic foot of wet marl as it usually occurs in the natural deposits contains 47.5 pounds of marl and 48 pounds of water." Eckel states² that in making cement from a mixture of marl and clay, it is necessary to excavate and transport over 1000 pounds of raw material for each barrel (380 pounds) of finished cement. The evaporation of this moisture involves either a long period of exposure to the air or else an expenditure of heat in kiln drying which is very large.

The manufacture of lime from marl requires that the latter be briquetted before entering the kiln, and this necessitates the evaporation of most of the moisture. The employment of marl in this way does not appear economically practical except in places where suitable limestones are not to be had.

The purpose for which marl seems best adapted is for the improvement of soils, in which use it takes the place of crushed limestone and calcined lime. It may be regarded no doubt as quite the equal of crushed limestone for application on land since it is in sufficiently fine condition to be soluble, at least slowly, in the soil waters and in respect to content of the calcium oxide, the effective base, it is superior to most limestones. The wide distribution of marl makes this source of agricultural lime available in many places where suitable limestones do not exist. Another factor in its favor is that the development of a marl deposit is relatively inexpensive as compared with cost of opening a quarry. Although very little marl is now produced for this purpose, the total output amounting only to a few thousands of tons a year, the wider use of this resource would both be an economy and an advantage to agricultural interests.

References

- Hall, James. Geology of New York. Report on Fourth District, 1843
Marshall, W. B. Report on Deposits of Marl and Peat in the Town of New Baltimore, Greene county. N. Y. State Mus. 45th Ann. Rep't, 1892, p. 45-52

¹ U. S. Geol. Surv. 22d Ann. Rep't, pt 3, p. 657.

² U. S. Geol. Bul. 522, p. 59.

Ries, H. & Eckel, E. C. Lime and Cement Industries of New York. N. Y. State Mus. Bul. 44, 1901

Vanuxem, Lardner. Geology of New York. Report on Third District, 1842

MICA

The production of mica has never attained the basis of a settled industry in this State, although small quantities are extracted from time to time in an experimental way as a secondary product in the mining of other minerals. The occurrences illustrate the general types of deposits which have commercial importance elsewhere as sources of mica and are distributed over the two great crystalline rock areas of the Adirondacks and the southeastern Highlands, being found in Orange, Putnam and Westchester counties in the Highlands, and in Saratoga, Essex, St Lawrence, Jefferson, Herkimer and other counties in the northern area. It is the purpose of the present article to give some particulars regarding the character and economic features of the deposits which hitherto have received little more than casual attention.

Mica is a general term for a group of minerals, of which three varieties find commercial use. These include muscovite, biotite and phlogopite. Muscovite is often called white mica, in allusion to its transparent quality, but it is not necessarily light or highly transparent, though the best commercial kinds are thus characterized. Some muscovite from the Adirondack pegmatites has a smoky gray color, nearly as dark as some examples of biotite. Chemically it contains potassium and sodium as basic elements, and is therefore an alkali variety. Biotite, as a rule, has a dark brown to nearly black color, but occasionally is sufficiently light to be transparent in thin sheets. Iron is present in considerable amounts and with the dark color renders it unsuitable for many purposes. Phlogopite is a magnesian variety, containing no iron, but less transparent usually than the best muscovite. Its color is amber or yellow, sometimes red or of a greenish tinge. It is employed for the same purposes as muscovite, but seems to be even preferred to the latter in electrical work. The distinction of the different varieties of mica when not apparent from outward appearance requires the use of a polarizing microscope, supplemented possibly by chemical tests to determine the nature of the basic elements.

Muscovite and biotite are allied in their occurrence, both being important ingredients of the crystalline silicate rocks such as granite, and many gneisses and schists. Typical granite contains both

varieties. The commercial sources of the two minerals, however, are limited to pegmatites, those modifications of granite in which the minerals are coarsely crystallized and irregularly distributed. Pegmatite is found in rather limited bodies, usually in dikes or lenses, which have intrusive relations with the country formations, more rarely as irregular masses within normal granites. The dikes or lenses range from very small examples, a few inches or a foot or two thick, up to bodies several hundred feet in diameter and of much greater length. They afford feldspar, quartz and other commercial materials in addition to mica.

Phlogopite is seldom if ever found in granite pegmatites, but its occurrence in New York is practically restricted to crystalline limestones where it appears to represent a secondary product of metamorphism, probably in most cases as a result of contact influences exerted by igneous intrusions. It is associated with such other minerals as amphibole, pyroxene, wernerite, tourmaline, fluorite, titanite and apatite. The mineral association varies from place to place and the occurrence of phlogopite is quite irregular or bunched, or else restricted to a definite part of the contact zone. According to the report of Cirkel,¹ the commercial phlogopite deposits of Canada are associated with pyroxene which penetrates country gneisses and limestones in the form of dikes, the pyroxene being regarded as an igneous rock. There is no resemblance to such conditions in the Adirondack occurrences, though pyroxene is a frequent accompaniment of the mica. The minerals rather have resulted from a conversion of the limestones by mineralizing solutions and vapors given off by granite intrusions, and they gradually disappear with increasing distance from the contacts, giving way to normal crystalline limestones. There is little regularity in the shape of such contact zones; in fact a highly irregular form may be said to be the prevailing one. Their nature and mineral content are even more variable than in the case of pegmatites.

The working of mica deposits in this State, as well as in most sections of the country, has been a rather uncertain business. Of necessity, it involves small-scale individual operations. The technical difficulties surrounding the industry are such that they do not admit of the methods employed in other branches of mining and the adoption of labor-saving devices that might tend to reduce costs. Labor conditions, therefore, exercise a great influence upon the course of mining operations. The principal mining activity in this country at present is in North Carolina, where according to the

¹ "Mica, Its Occurrence and Uses." Mines Branch, Department of the Interior, Ottawa, 1905.

article by Sterrett in *Mineral Resources* for 1912, volume 2, there are probably as many as a hundred separate mines and prospects, many worked by farmers in the off-season of their labors. As the entire output of the country in recent years has been well under \$400,000 annually, the average outturn from the individual mines evidently is very small. India contributes most of the mica consumed in the United States, though Canada is an important source of the electrical grades. It has been stated (Mineral Industry for 1912) that the cost of labor in the production of mica in India is about one-sixth of the labor cost in the domestic mines.

The quality of mica depends upon a great many factors which can be estimated accurately only by the expert. Of the three varieties, biotite has more limited use than the others and the market does not warrant mining operations for its production alone. It is obtained mainly as a by-product in the working of pegmatites for feldspar. Owing to its iron content it is not much used for electrical insulation, which is the principal application for the colored micas. Muscovite, having the greatest transparency, is preferred for glazing and for lamp chimneys, shades and similar purposes. The larger sizes only can thus be used. For electrical insulation in motors and dynamos, phlogopite seems to find the most favor, on account of the softer nature of that variety, it is said. Much of the electrical mica is used in the form of "micanite," which consists of small sheets cemented and compressed into boards. The presence of inclusions of iron oxid, usually magnetite, which is quite common in muscovite and phlogopite, is stated by Sterrett to have no injurious effect upon the quality of the electrical mica.

Much of the mica as found in pegmatites and contact zones, even when in large crystals, can not be used in sheet form on account of the numerous fractures and lines that traverse the surfaces. There is great variation in the splitting quality of mica from different places, some examples cleaving readily and cleanly even to very thin sheets and others showing a splintery surface. The average size of sheet that can be obtained largely determines the value of a deposit, since the prices rapidly decrease with the size. The waste in the splitting is sometimes turned into use by converting it into ground mica for which there exists a more or less ready market in the making of lustrous coated papers, lubricants and insulating materials.

Field Occurrence

Orange county. Phlogopite of greenish color is found in a pyroxene rock near Lake Mombasha, town of Monroe. The locality

is mentioned by Beck in the reports of the First Survey as being on the bank of the stream flowing from "Mount Basha" pond, near the Forshee iron mine. It is a contact deposit in limestone of which there are exposures in the vicinity of the mine mentioned and also farther north around the opening of the O'Neil mine. Amphibole, pyroxene, garnet and probably magnetite bodies themselves are accompanying results of the contact action. The occurrence is mentioned by Whitlock¹ as having been worked in 1903. Sheets have been mined that measured as much as three feet in diameter.

Warwick. According to Whitlock² muscovite occurs near Greenwood lake, 8 miles southwest of Warwick, in a pegmatite vein, the plates reaching a foot in diameter. There are numerous other occurrences of muscovite in this vicinity, as pegmatite has a wide distribution in the crystalline areas of the Highlands.

Westchester county. A deposit of mica near Pleasantville was at one time the object of mining operations. The occurrence is in pegmatite and the mica belongs to the muscovite variety. The sheets contain magnetite inclusions.

Muscovite is found in considerable quantity in parts of the Kinkel feldspar quarry at Bedford, but is not of commercial quality, except possibly for ground mica.

Putnam county. The occurrences in this county have not afforded any commercial mica so far as known.

Essex county. Mica is found in the pegmatite bodies at Crown Point and Ticonderoga now worked. The chief variety is biotite. Occasional shipments of scrap mica recovered in the milling of feldspar are made by the Crown Point Spar Co. The material is ground and used in paint.

Large crystals of biotite have been taken from various localities in the town of Keene.

Saratoga county. A pegmatite body about 2 miles north of Batchellerville, town of Edinburg, was worked some years since by the Claspka Mining Co. for feldspar. Several tons of muscovite were taken out in the course of the operations, the mineral occurring in the spaces between the larger feldspars, or intergrown with the latter. The crystals measure up to a foot or more in diameter and half that in thickness, many bearing very perfect prismatic boundaries. Inclusions of magnetite arranged in regular lines are frequent.

¹ Minerals not Commercially Important, N. Y. State Geologist 23d Ann. Rep't, 1903, p. 191.

² Op. cit.

The muscovite has little value for sheet cutting, being much fractured and splintery.

Biotite in sheets up to 2 feet across are also found here.

Warren county. A pegmatite occurrence near Chestertown has been under development at different times and has afforded small quantities of commercial mica, including muscovite and biotite. The locality is mentioned in the Mining and Quarry Report for 1911 under the head of Feldspar, which is also present in marketable quality. It is 3 miles south of Chestertown on the ridge to the east of the Warrensburg road. Two openings were made over 15 years ago, and in 1913 further work was carried on by C. A. Williams who informed the writer that he secured some merchantable book mica and plans to continue operations during the current season. The main opening is a pit 15 feet wide extended for 75 or 80 feet along the course of the pegmatite which strikes northeast. The full size of the body could not be ascertained at the time the writer visited the locality as only the easterly wall was exposed. The pegmatite is a coarse aggregate of white microcline, quartz and mica. Biotite seems to be chiefly represented near the outcrop, but Mr Williams states that recent work has uncovered muscovite in larger amount. The books run to a foot or so in diameter and usually show fractures or rulings. Black tourmaline occurs sparingly in the quartz and feldspar, but it would appear that feldspar of pottery grade may be obtained with a little sorting. A smaller pit lies to the north of the other, the result of the earlier operations, and is thought to be on the same pegmatite body, in which case the occurrence must be quite extensive.

Jefferson county. Yellow mica, probably phlogopite, is found in large plates near Henderson. Muscalonge lake, town of Theresa, has afforded fine examples of crystallized phlogopite of brown color, but in small individuals.

St Lawrence county. Some fine examples of phlogopite crystals in the State Museum are recorded as having been collected from Somerville. Perfect six-sided prisms unmarked by fractures or rulings and of brown color have a diameter of 12 inches. The exact locality is not given, but it may be the same mentioned by Beck as 2 miles north of Somerville, with limestone and serpentine as the gangue materials. Judging from the samples, the occurrence is of unusual interest.

Small quantities of mica have been obtained from the town of Fine, 2 miles north of Oswegatchie. Good sheets of reddish phlogopite were shown to the writer as coming from that locality. The last work on the deposit was in 1909.

Muscovite is found in Edwards associated with the fibrous talc. It is not, however, of commercial importance.

St Lawrence county may be regarded as one of the more favorable sections for the occurrence of commercial grades of mica. Granite intrusions of great size have taken place at different times in the Precambrian and on their borders may be found dikes and lenses of pegmatite intersecting the older gneisses and schists. Since the intrusion of the pegmatites there has been no great disturbance from regional-metamorphic forces so that the mica is little fractured in most occurrences, whereas the pegmatites in the central Adirondacks often show the effects of severe compression. The pegmatites carry both muscovite and biotite. The numerous contacts of limestone and granite afford favorable conditions for the occurrence of phlogopite, which, as stated, is found here and there in specimens of commercial quality, though the real importance of the deposits has never been adequately tested. The geological relations in this part of the Adirondacks are very similar to those in the mica-mining districts of Canada.

MILLSTONES

The production of millstones or burstones is carried on in a small way in the Shawangunk mountain area from the grit which outcrops along the northern edge of the ridge. The industry has been established a long time and for many years enjoyed prosperous conditions through the extensive sale of the product for cereal mills. This market has been gradually curtailed within the last quarter of a century or more by the introduction of the roller mill process for making flour, although some mills still retain burstones for grinding the coarser cereals. At present the quarrying and shaping of the stones gives employment to a small number of men who engage in it during a few months of the year when not otherwise employed. The product is sold chiefly among the small corn mills in the south. Besides millstones, the quarries also turn out disks of stone which are called chasers and are employed in the roll type of crusher, the disks revolving on edge in a circular pan that is sometimes paved with blocks of the same stone. This type of crusher is used more or less in the pulverization of materials like quartz, feldspar, barytes and mineral paints.

Occurrence of grit. The Shawangunk grit is a hard firmly cemented pebbly sandstone of light gray color. The beds range from 50 to 200 feet, thinning progressively toward the northeast. The layers differ in texture, ranging from a medium-grained sandstone or quartzite to a coarse conglomerate in which the individual

pebbles reach a diameter of 2 inches or so. The pebbles consist of milky white quartz such as occurs commonly in veins and are fairly rounded, showing considerable abrasion during the stage of their accumulation and deposition on the shores of the interior sea on which the beds were laid down.

The cementing substance of the grit is white silica which forms a matrix for the grains but does not wholly fill the voids; thus producing the bur or cutting surface characteristic of the millstones. The grit is nearly pure quartz and has found application in years past for glass manufacture.

Shawangunk mountain extends from the vicinity of High Falls near Kingston southwest into New Jersey and Pennsylvania and is capped by the grit beds which overlie the Hudson River shales, the whole dipping steeply to the northwest. Material suited to millstone manufacture occurs here and there along the slope of the ridge, in the section between Kerhonkson and High Falls. Some of the localities where extensive quarry operations have been carried on are Kyserike, St Josen, Granite and Kerhonkson. In addition New Paltz and Kingston have been identified with the industry as shipping centers.

Quarry methods. The quarry operations are simple and require little equipment, as the amount of stone handled is relatively small. The layer or layers of desirable quality are uncovered by stripping of the overlying soil and rock, and then lifted out by bars and wedges, perhaps assisted by light charges of powder to loosen them from the bed. Blasting, however, is avoided as much as possible lest the stone be weakened. The size of the block is determined by the spacing of the natural joint planes. The block when removed from the bed is roughly squared up and then worked into a disk with the aid of hand hammer and point. The last operation is to drill the center hole or eye. This is usually done by starting a hole in the center of one of the sides and drilling half way, then reversing and cutting a second hole on the opposite face to meet the first. The round eye thus formed may be squared up. The dressing or grooving of millstones is not done at the quarry. Millstones are sold in pairs.

Production. Considerable difficulty is encountered in obtaining information about the production of millstones. Values of course are dependent upon the quality and size of the stones and the quarry prices range all the way from \$2.50 to \$3 for the smallest size, an 18-inch stone, to \$75 or more for an 84-inch stone which is about the maximum size that is used. The quarrymen may sell the whole

or part of their year's product to local middlemen who sometimes work quarries of their own. In the last decade the average production has been less than \$20,000, although in earlier years it often exceeded \$100,000. The statistics herewith include the output of chasers as well as millstones.

Production of millstones since 1904

1904.....	\$21 476	1912.....	\$15 358
1905.....	22 944	1913.....	13 130
1906.....	22 442	1914.....	12 410
1907.....	21 806	1915.....	10 916
1908.....	18 341	1916.....	10 287
1909.....	19 247	1917.....	22 103
1910.....	6 613	1918.....	25 488
1911.....	13 177		

References

- Mather, W. W.** Geology of New York. Report on First District, 1843, p. 357
Nason, F. L. Economic Geology of Ulster County. N. Y. State Mus. 47th Ann. Rep't, 1894

MINERAL PAINTS

Natural mineral pigments are referred to here, such as are made by the physical preparation of an ore or mineral aggregate. They constitute only a part of the products of the paint industry in general prepared from mineral bases, as the more important branch is that of manufacturing lead pigments. These require elaborate chemical operations upon which depends the particular coloring quality of the pigments, and all the metallic lead thus used is derived from sources outside of the State. In making the natural pigments, on the other hand, the mineral materials are simply washed or ground to secure the desired degree of fineness, with a resort to calcination in some cases to improve the color.

The raw materials or bases of the natural mineral paints that occur in New York include iron ores, shale or slate, and ochers. In all the principal coloring agent is an iron compound and usually the ferric oxide, hematite, or the ferric hydrate, limonite. Reds, browns and yellows are the common colors produced.

Metallic paint may be made from hematite of earthy or massive nature, or from limonite. It is also prepared by calcination of siderite, ferrous carbonate or spathic iron ore, of which the natural gray color changes to red in the operation through the conversion of the carbonate into hematite. The iron sinter from the roasting of pyrite in acid manufacture is also sometimes employed for the

purpose. The iron ore pigments have good covering power and are resistant to atmospheric influences; they are largely used for outside work in coating wood and iron structures and metal roofs.

The principal material for metallic paint that occurs in the State is the Clinton hematite, which is mined quite extensively for iron ore. There are two kinds of the ore — the oölitic variety that occurs in the section about Clinton, Oneida county, and the fossil ore from the western part of the belt in Wayne county. The former has a silica base, the latter a carbonate one, and the ground product of each has a somewhat different color and quality. The manufacturing operations consist of roasting to get rid of the moisture and volatile matter and grinding to fine powder. The product is mostly sold in dry state.

The red hematite from the St Lawrence-Jefferson county district has been employed for metallic paint to a small extent. This ore differs from the Clinton hematite in its structure, being finely divided and without oölitic or fossil characters. Much of it is too hard for paint, but some deposits yield soft material which can be ground successfully. The paint stock has been produced mainly at Rossie, St Lawrence county.

No metallic paint is being made at present from limonite or carbonate ores, although these occur in quantity in southeastern New York. Limonite gives a brownish yellow color; the carbonate a red which is brought out by calcination and differs somewhat from the red of natural hematite.

Mortar colors are prepared from the same materials as metallic paint. They are used in tinting mortar, concrete and artificial stone.

Some kinds of slate and shale possess decided colors by reason of the iron oxides they contain, as well as suitable textures for grinding into paints. Such slate pigments, as they are known in the trade, have a weaker coloring capacity than the ground ores, although they may contain enough iron to give a close resemblance to metallic paints. They yield a somewhat wider variety of tints, being found in purple, bluish gray, red, brown and even black colors, the last being the result of admixed carbonaceous matter. They have an argillaceous base like ocher, but contain less water and are more compact.

The principal material used for slate pigment is the Cambrian red slate of Washington county, well known as a roofing slate and possessing a durable deep-red color. There are quarries of it in Granville and Hebron townships. The waste material from the

spoil banks is used for grinding and it is to be had in practically unlimited supply. Lately, the material is being utilized for making prepared roofing as well as for pigment. The red color comes from hematite in finely divided condition and as coating of the quartz and silicates which make up the body of the slate. The slate is hard and contains very little water. Shales that are intermediate between slate and clays in hardness occur in the Silurian and Devonian beds. At Roxbury, Delaware county, an occurrence of red shale in the Catskill series has supplied material for paint. Another source is the red Vernon shales which have been worked in Herkimer county. In the Chemung formations of Cattaraugus county occur red, brown and bluish shales that have been worked in the vicinity of Randolph.

Ocher, a limonitic clay, is formed by the surface weathering of iron-bearing rocks of various kinds, chiefly limestones. It is not plentiful in New York owing to the fact that the residual materials of rock decay have been mostly swept away by the Pleistocene ice-sheet. An occurrence on Crane mountain, Warren county, represents one of the few deposits of residual clays that escaped erosion by its protected position in a deep notch. It was worked years ago, but little is known as to the operations, and the pits are now inaccessible.

Ocherous clay occurs as a cover to some of the limonite deposits of Dutchess and Columbia counties; its quality for paint purposes has not been investigated so far as can be learned.

Sienna is a variety of ocher that contains manganese oxide in addition to limonite and has a brown color, darker than ordinary ocher, but lighter than umber. The only recorded occurrence of it is near Whitehall, which was worked for a short time 10 years or more ago. The deposit consisted of a seam in the surface clays and was said to have been exhausted.

MINERAL WATERS

The production of mineral and potable spring waters for public sale constitutes an important branch of the mineral industry of the State, though perhaps seldom considered in that light. Not only is a large revenue derived from the bottling and shipment of such waters, but some of the spring localities by virtue of their waters have become favorite resorts for tourists and health seekers and thus become indirect sources of income of large importance. Saratoga Springs, Ballston Springs, Richfield Springs, Sharon Springs and Lebanon Springs are among the number that will be first called

to mind in such connection. They illustrate also the variety of waters which are to be found within the State limits. Numerous other springs are more particularly adapted for table use containing only sufficient mineral matter perhaps to give them a saline taste. Both kinds of water are generally carbonated and sold in bottles.

Of late years there has developed an important business in the sale of spring waters which can hardly be classed as mineral in the common acceptance of the word, but which are extensively sold for office and family use in the larger towns and cities. Their employment depends upon their freedom from harmful impurities in which feature they are generally superior to the local supplies. In so far as waters are an article of commerce they may well be included in a canvass of the mineral water industry. They are usually distributed in large bottles or carboys in non-carbonated condition.

Character of the mineral waters. Among the spring waters that contain mineral ingredients in appreciable quantity, those characterized by the presence of alkalies and alkaline earths are the most abundant in the State. The dissolved bases may exist in association with chlorine and carbon dioxide as in the springs of Saratoga county or they may be associated chiefly with sulphuric acid as illustrated by the Sharon and Clifton springs. The mineral waters of Saratoga Springs and Ballston Springs are found along fractured zones in Lower Silurian rocks. The reservoirs occur usually in the Trenton limestone and are accompanied by free carbon dioxide which is evolved in large amount when the waters are led to the surface and the pressure released. In addition they contain chlorine, sodium, potassium, calcium and magnesium in variable amounts. The proportion of solid constituents in the different waters varies from less than 100 to over 500 grains a gallon. In some of the wells of the Saratoga springs the waters contain as much as five or six volumes of carbon dioxide, the gas being so abundant that its collection and distribution was at one time an industry of considerable importance in that vicinity. Large quantities of table and medicinal waters are bottled at Saratoga for shipment to all parts of the country.

The waters at Richfield Springs contain the elements of the alkalies and alkaline earth groups together with sulphuric acid and smaller amounts of chlorine, carbon dioxide and sulphureted hydrogen. They are employed for medicinal baths as well as for drinking purposes. The springs issue from the drift and their source is apparently along the contact of the Onondaga limestone

and Marcellus shales. Sharon Springs is situated to the east of Richfield Springs and near the contact of the Ordovician and Silurian strata. Clifton Springs, Ontario county, and Massena Springs, St Lawrence county, are among the localities where sulphureted waters occur and are utilized.

The Oak Orchard Springs in the town of Byron, Genesee county, are noteworthy for their acid waters which contain a considerable proportion of alumina, iron, calcium and magnesium besides free sulphuric acid. Waters highly charged with calcium chloride are sometimes encountered in deep wells drilled within the area of the rock salt deposits which underlie much of the area to the west and south of Oneida lake. These waters are employed at one or two places for medicinal baths.

The Lebanon spring at Lebanon, Columbia county, is the single representative in the State of the class of thermal springs. It has a temperature of 75° F. independent of seasonal variations and is highly charged with carbon dioxide and nitrogen.

Ordinary spring waters. The greater quantity of spring waters consumed in the State belongs to the nonmedicinal, noncarbonated class represented by such springs as the Great Bear, Deep Rock, Mountain View, Sun Ray, Chemung etc. The waters are obtained either from flowing springs or artesian wells and are shipped in carboys or in tank cars to the principal towns and cities where they are bottled and distributed among the individual consumers. The essential feature of such waters is their freedom from noxious impurities. This is generally safeguarded by the care in the handling of the waters, which may be also regularly examined as to purity by chemical laboratories.

List of springs. The following list includes the names of localities of most of the springs in the State that are employed commercially or have been so employed in the past.

NAME	LOCALITY
Baldwin Mineral Spring.....	Cayuga, Cayuga county
Coyle & Caywood (Arrowhead Spring)...	Weedsport, Cayuga county
Diamond Rock Spring.....	Cherry Creek, Chautauqua county
Cassadaga.....	Stockton, Chautauqua county
Breesport Oxygenated Spring.....	Breesport, Chemung county
Breesport Deep Rock Water Co.....	Breesport, Chemung county
Chemung Valley.....	Elmira, Chemung county
Deep Rock.....	Breesport, Chemung county
Chemung Spring Water Co.....	Chemung, Chemung county
Whites.....	Norwich, Chenango county
Dietade.....	Keeseville, Essex county

NAME	LOCALITY
Keeseville Mineral Spring.....	Keeseville, Essex county
Lebanon Mineral Springs.....	Lebanon, Columbia county
Greendale Crystal Springs.....	Livingston, Columbia county
Mount Washington Spring.....	Hillsdale, Columbia county
Trespur Spring.....	McGraw, Cortland county
Arlington Spring.....	Arlington, Dutchess county
Mount Beacon Spring.....	Mount Beacon, Dutchess county
Mount View Spring.....	Poughkeepsie, Dutchess county
Monarch Spring Water Co.....	Beacon, Dutchess county
Elk Spring Water Co.....	Lancaster, Erie county
Aldena Park.....	Alden, Erie county
Diamond Rock.....	Lancaster, Erie county
Sparkling.....	Buffalo, Erie county
Oak Mountain.....	Dolgeville, Fulton county
W. A. A. Heek.....	Tupper Lake, Franklin county
Eagle Spring.....	Edgewood, Greene county
White Bear.....	Batavia, Genesee county
Oasis Cold Spring.....	Bergen, Genesee county
McManus.....	Jefferson county
Red Rock.....	Fine View, Jefferson county
Swan.....	Alexandria Bay, Jefferson county
Valley.....	Omar, Jefferson county
Crystaldale.....	Crystaldale, Lewis county
M. Nortz & Sons.....	Lowville, Lewis county
Nunda Mineral Springs.....	Nunda, Livingston county
Mohawk Spring.....	Amsterdam, Montgomery county
Table Rock Mineral.....	Honeoye Falls, Monroe county
Garden City Well.....	Garden City, Nassau county
Sagamore.....	Oyster Bay, Nassau county
Clinton Lithia Springs, Inc.....	Franklin Springs, Oneida county
Glen Alex Spring.....	Washington Mills, Oneida county
Lithia Polaris Spring.....	Boonville, Oneida county
F. H. Suppe (Franklin Lithia Springs)...	Franklin Springs, Oneida county
Orville Risley.....	New York Mills, Oneida county
Cold Spring.....	Utica, Oneida county
Paris Spring.....	Sauquoit, Oneida county
Split Rock Lithia.....	Franklin Springs, Oneida county
Warner Artesian Well.....	Franklin Springs, Oneida county
Westmoreland Mineral.....	Westmoreland, Oneida county
Geneva Mineral Water Springs.....	Geneva, Ontario county
Orange Great Rock.....	Middletown, Orange county
Crystal Spring.....	Whitesboro, Oneida county
Deep Rock Spring.....	Oswego, Oswego county
Great Bear Spring.....	Fulton, Oswego county
Richland.....	Richland, Oswego county
White Sulphur Spring.....	Richfield Springs, Otsego county
Black Rock Spring.....	Ren-sealer, Rensselaer county
Mammoth Spring.....	North Greenbush, Rensselaer county
Shell Rock Spring.....	East Greenbush, Rensselaer county
Flint.....	West Sand Lake, Rensselaer county

NAME	LOCALITY
Ideal.....	Troy, Rensselaer county
Plymouth.....	North Greenbush, Rensselaer county
Standard.....	Troy, Rensselaer county
Carrier.....	Potsdam, St Lawrence county
Madrid Indian Spring.....	Madrid, St Lawrence county
Massena Springs.....	Massena, St Lawrence county
Artesian Lithia Spring.....	Ballston Spa, Saratoga county
Comstock Mineral Spring.....	Milton, Saratoga county
Mohican Spring.....	Ballston Spa, Saratoga county
Arondack Spring.....	Saratoga Springs, Saratoga county
Hathorn Nos. 1 and 2 Springs.....	Saratoga Springs, Saratoga county
Coesa Spring.....	Saratoga Springs, Saratoga county
Geyser Spring.....	Saratoga Springs, Saratoga county
Minnonebe Spring.....	Saratoga Springs, Saratoga county
Orenda Spring.....	Saratoga Springs, Saratoga county
Saratoga Gurn Spring.....	Saratoga Springs, Saratoga county
Saratoga Vichy Spring.....	Saratoga Springs, Saratoga county
Old Iron.....	Ballston Spa, Saratoga county
Congress No. 2.....	Saratoga Springs, Saratoga county
Ferndell.....	Saratoga Springs, Saratoga county
Chalybeate Spring.....	Sharon Springs, Schoharie county
Eye Water Spring.....	Sharon Springs, Schoharie county
Sulphur-Magnesia Spring.....	Sharon Springs, Schoharie county
White Sulphur Spring.....	Sharon Springs, Schoharie county
Red Jacket Spring.....	Seneca Falls, Seneca county
Pleasant Valley.....	Rheims, Steuben county
Setauket Spring.....	Setauket, Suffolk county
Ithaca.....	Ithaca, Tompkins county
Elixir Spring.....	Clintondale, Ulster county
Pine Hill Crystal Spring Water Co.....	Pine Hill, Ulster county
Sun Ray Spring.....	Ellenville, Ulster county
Vita Spring.....	Fort Edward, Washington county
Vermont Mineral Spring.....	Granville, Washington county
Briarcliff Lodge Association.....	Briarcliff Manor, Westchester county
Gramatan Spring Water Co.....	Bronxville, Westchester county
Granite Spring.....	Granite Springs, Westchester county
Orchard Spring.....	Yorktown Heights, Westchester county
Mokobo Spring.....	Mount Kisco, Westchester county
Skenorock Spring.....	Baldwin Place, Westchester county

References

- Kemp, James F. The Mineral Springs of Saratoga. N. Y. State Mus. Bul. 159, 1912
- Peale, Albert C. Mineral Springs of the United States. U. S. Geol. Surv. 14th Ann. Rep't, 1894

MOLYBDENITE

This mineral has not been mined in New York but it occurs in a number of localities and possibly may be present somewhere in economic quantity. It is the principal ore of the rare metal molybdenum, for which a demand has developed of late in connection with the manufacture of alloy steels for special uses. One of the applications of molybdenum steel is in the lining of heavy ordnance; it is said to be more resistant to erosion from the gases of high explosives than other kinds of steel, and guns so lined consequently give prolonged service. Molybdenite is a sulphide (MoS) and bears a striking resemblance in physical characters to graphite. It is soft, of lead gray color and occurs in small scales and thicker plates, rarely showing hexagonal outlines. Its streak on glazed porcelain has a greenish tint quite distinct from the grayish black graphite, the best physical test for its recognition.

Molybdenite has a fluctuating market, but ordinarily is in request at prices which make a deposit of economic interest that carries only 1 or 2 per cent of the mineral. A deposit of this kind should be large and the ore amenable to concentration without excessive loss of the valuable mineral. Owing to its softness, molybdenite crushes readily into powder and then is separated with difficulty. Flotation has been applied successfully to ores containing disseminated molybdenite, such as are mainly represented in this State.

The mineral is found in various associations, but more especially with granitic rocks and their offshoots and along contacts between granite and limestone. Several localities for its occurrence have been listed by Whitlock¹, as follows: Manhattan Island, between 43d and 44th streets and First and Third avenues, in mica schist; West Point, Orange county, in gneiss; Constitution island (Hudson river off West Point) in gneiss; Warwick, Orange county, in limestone; Tilly Foster mine, near Brewster, Putnam county, in serpentine; North Russell, St Lawrence county, gneiss-limestone contact. Of these localities the one in New York City is no longer accessible. From what has been learned indirectly it is evident that the West Point, Constitution island and Warwick occurrences have little or no interest except from a collector's standpoint. At the Tilly Foster mine molybdenite occurs sparingly as a contact mineral in metamorphosed limestone and is no longer to be found except in the waste dumps of the former workings.

The Russell locality, about which little was previously known, was visited in 1917 by A. F. Buddington, who communicated to the

¹ New York Mineral Localities. N. Y. State Mus. Bul. 70, 1903.

writer the following account of it. "The molybdenite is found in a green pyroxene rock which has been prospected in a small way for copper. There are few indications of copper, although the rock carries considerable pyrite in thin lenticular bands. Molybdenite occurs in disseminated flakes and aggregates of flakes, some of which attain a size of an inch or so in diameter and an eighth of an inch thick, but mostly are much smaller. The mineral seems to be rather sporadic, and at best too sparsely represented to justify mining operations. The occurrence belongs to the contact type, as the pyroxene country rock is the result of alteration of limestone by granite, being in fact enclosed by a body of granite gneiss that no doubt has been the agency of metamorphism and introduced the metal. The wall rock is traversed by veins of a coarse phlogopite-pyroxene material which seems to be free of molybdenite. The property in which the prospect lies is just south of Boyd pond, near Russell, and is owned by Martin Leary."

In the course of field work in the northern part of Lewis county A. F. Buddington discovered a new molybdenite occurrence, of which he has given the following details. "The locality is on the farm of William J. Aucter, in the town of New Bremen, three-fourths of a mile southeast of Bushes Corners. It is reached most conveniently from Croghan, the terminus of a branch railroad from Lowville. The mineral is distributed through the mass of a granite intrusion, or rather within indefinitely bounded veins of pegmatite that occur in the granite. The latter rock has a gneissic appearance and weathers to a reddish color, but is green to pink on fresh surfaces. It may represent a phase of the green syenite that outcrops to the northwest of the described locality. Altogether four narrow pegmatite bands were noted, each scarcely more than one inch wide, exposed on the face of a sloping ridge for a distance of 25 feet. The flakes are relatively coarse and will average from one-quarter to 1 inch in diameter. Traces of the mineral are found at other points along the same ridge. A hill of coarse red gneiss, one-half of a mile south of Stiffts schoolhouse, west of the highway, also shows its presence. The locality is one that deserves more careful investigation and possibly some exploration in the hope of uncovering larger veins of pegmatite than those exposed, which on the whole are fairly rich."

An occurrence of molybdenite on the Owens farm, now a part of the Stuyvesant Fish estate, north of Peekskill, came to the writer's notice a few years ago. The locality is just south of the Catskill aqueduct on the west side of Sprout Brook valley. The

mineral is found in rusty gneiss, made up largely of pyroxene, showing a greenish color in fresh fracture. The rock appears to be of contact nature, formed by the alteration of limestone in the vicinity of some igneous intrusion, but neither limestone nor intrusive rock is exposed in the immediate vicinity. The ledge can be traced for several hundred feet, but the molybdenite seems to be restricted to a small area, and the richer ore is in limited amount. The molybdenite occurs in disseminated flakes, mostly from one-eighth to one-fourth of an inch in diameter, and is present in some samples to the extent of 2 or 3 per cent or more. A little exploration, consisting of a shallow pit within the rich zone, has been performed. If any considerable body of ore like that in the ledge could be found in the vicinity, it would undoubtedly be of commercial importance.

Another locality for molybdenite was reported by Mr Stuyvesant Fish to have been found recently in the northern part of Cortland township, about 3 miles from Peekskill. This occurrence is in limestone and probably thus represents a similar contact development to the first. No doubt the effective agency in the metamorphism and mineralization of the limestone has been granite which is widely represented in this part of the Highlands.

NATURAL GAS

Natural gas is a commercial product in several of the central and western counties of New York. The stocks of this valuable fuel are not large as compared with those that have been discovered in other parts of the Appalachian field to which the New York district belongs but they are usually easily accessible for development and close to industrial centers which absorb the output at remunerative prices. There is a potential market within the gas region for many times the present production, so that every incentive exists for guarding against waste in production and for pushing exploratory work into all territory that might add to the flow. The search for gas outside of the established districts has been quite actively carried on in the last few years, but so far it has not led to any notable new finds.

Historical. The production of natural gas is not a new industry in this State. Gas wells for the supply of light to households were in use in Chautauqua county in the first half of the 19th century. There is a record of the drilling of shallow wells in Fredonia, where gas seepages attracted the attention of the pioneer settlers, as early as 1821. The same community is still supplied by wells located in the vicinity — many of the inhabitants owning private wells for

the supply of one or two families — which testifies to the permanency of flow characteristic of some of the pools of the State. The extensive use of natural gas for municipal purposes and industrially did not begin, however, until after 1864 when the discovery of the oil and gas district in Cattaraugus county gave the first impulse to the systematic exploration of these resources. Allegany county was the next important source that was discovered, the first large wells in that section having been drilled about 1880, of which many yielded both oil and gas.

The two counties just named, with the western section of Steuben county, constitute the southwestern district which lies next to the Pennsylvania border. The pools that yield the oil, as well as producing all of the gas in the earlier years, are found in the higher Devonian strata which constitute the main sources of supply in the Appalachian field to the south. Thus the development of this district came as a natural sequence to the opening of the oil and gas region of western Pennsylvania of which the southwestern New York area may be considered as a northerly extension, both geologically and geographically.

Following the successful developments in this region, exploration was extended into the adjoining counties and beyond the areal limits of the uppermost Devonian rocks in which alone gas had so far been discovered. In 1887 the Buffalo Cement Co. drilled a successful well on its property within the city limits of Buffalo, after having put down two holes that proved practically dry. Drilling in the vicinity was actively undertaken in the next few years, particularly in the town of West Seneca, south of Buffalo, and a local company was organized to develop the supplies and make them available for general use. By 1895 the South Buffalo Natural Gas Co. had some 45 wells connected with its distributing lines in that city.

The Buffalo district lies on the outcrop of the Onondaga, Marcellus and Hamilton formations of the Middle Devonian, whereas the district of Cattaraugus and Allegany counties first opened falls within the Chemung series at the top of that system. Gas was encountered in the Lockport dolomite and Clinton limestone, but the main flow was from the white sandstone beds of the Medina, which later proved to be the most widespread and consistent gas reservoir in the western section of the State.

The appreciation of the importance of the Medina horizon for natural gas production has come through exploration carried on in the last 15 years or so in eastern and southern Erie county, in



Map of the New York oil and gas districts

the lake shore belt of Chautauqua county and in the interior districts included in Genesee, Monroe, Ontario, Livingston and other counties. The Medina is the most prolific of the New York gas formations and for a number of years has contributed considerably more than one-half of the annual flow for the entire State.

The development of local gas pools in the area around the east end of Lake Ontario resulted from experimental drilling that was chiefly carried out in the few years preceding and following 1890; this exploration was initiated independently of operations elsewhere in the State, as the conditions are widely different from those in the older fields. Perhaps the incentive for testing the possibilities of gas in the formations below the Medina came from the contemporaneous discovery of the great gas and oil fields in the Trenton formation of Ohio and Indiana. At any rate, as was brought out by Prof. Edward Orton's investigation, the main yield of gas in the Lake Ontario district comes from the Trenton limestone, the lowest horizon in which any considerable pools have been found up to the present. The particular beds that hold the gas are the extension underground of the Trenton belt which lies along the western margin of the Adirondacks and that in Jefferson county reaches from the Adirondacks foothills west to Lake Ontario and the St Lawrence river. They have a southerly dip and where tapped by the wells are covered by the shale formations of the Cincinnati group with an additional thickness of Medina shales in the more westerly localities. The productive pools so far exploited are restricted to Oswego county and the northern part of Onondaga county.

The Pavilion district represents the most important of the relatively recent discoveries of gas in the State. The first holes were drilled in 1906, since which time some sixty wells have been brought in which have maintained a very steady flow. It lies in the southeast corner of Genesee county, having Livingston county on the east and Wyoming county to the south. The gas horizon is in the upper Medina formation, the flow coming mainly from the last 20 feet of the sandstone, which here measures about 100 feet thick. The limits of the field seem to be fairly well marked out by the borings; it is one of the few districts in which sufficient data are obtainable to indicate the precise structural features surrounding the accumulations of the gas and for that reason is of much interest.

Production. The statistics of natural gas production for the years since 1897, covering the more active period, are given below. They are in part taken from *Mineral Resources*, published by the United

States Geological Survey and partly compiled from direct reports from the field.

Production of natural gas in New York

YEAR	NUMBER OF WELLS	PRODUCTION M CUBIC FEET	VALUE
1897.....	359	.....	\$200 076
1898.....	422	.....	229 078
1899.....	447	.....	294 593
1900.....	504	.....	335 367
1901.....	557	.....	293 232
1902.....	626	.....	346 471
1903.....	700	.....	493 686
1904.....	744	2 399 987	552 197
1905.....	839	2 639 130	607 000
1906.....	919	3 007 086	766 579
1907.....	925	3 052 145	800 014
1908.....	1 100	3 860 000	987 775
1909.....	1 280	3 825 215	1 145 693
1910.....	1 340	4 815 643	1 411 699
1911.....	1 403	5 127 571	1 547 077
1912.....	1 660	6 564 659	1 882 297
1913.....	1 750	8 555 429	2 549 227
1914.....	1 797	8 714 681	2 570 165
1915.....	2 051	7 810 040	2 335 324
1916.....	2 068	8 035 632	2 355 320
1917.....	2 078	8 371 747	2 499 303
1918.....	2 114	8 460 583	5 673 131

A steady gain in production has characterized the course of the industry during most of the period, a feature which may be attributed to the sustained flow of the pools supplemented by the increment obtained from a few new districts.

FEATURES OF DISTRIBUTION OF NATURAL GAS

The available area for the occurrence of natural gas may be broadly indicated by reference to the main geological elements of the State.

It is to be noted in the first place that the sedimentary rocks alone afford appropriate environment for the formation and storage of natural gas and petroleum. The derivation of both of these materials undoubtedly is traceable to the organic matter enclosed by the beds at the time of their deposition, and consisting probably of animal remains in large part, just as coal represents the accumulation of plant tissue under similar conditions. Of the different kinds of sediments, shales often contain noticeable amounts of

organic matter in the form of hydrocarbons, and occasionally carry so much of these that they may be of economic value for the production of oil by artificial distillation. In nature the process by which organic matter is converted into oil and gas goes on very slowly, but once under way it may continue for indefinite periods of time with cumulative results.

A large mass of shale may thus be considered favorable to the generation of oil and gas, but it is not necessarily significant of their existence in any locality in economic quantity. For this it is also essential that a suitable repository or place of storage be provided. Shales ordinarily are ill adapted for this purpose; they have too little pore space, and under pressure from an overlying load of sediments, their joints and seams, which near the surface afford some room for water, become tight through movements of the mass. Limestones, likewise are usually closely textured, but often contain cavities and openings produced by solution of underground waters, which may be connected into a more or less continuous series by the natural joints and bedding planes. They may have consequently a fairly high storage capacity and show considerable persistence in yield. The best materials for holding gas, oil or water are sandstones and unconsolidated beds of sand, whose porosity in individual examples ranges from 4 or 5 per cent to about 30 per cent. Their absorbing power varies with the size and the shape of the grains and the conditions with reference to bond. Estimates of the porosity of the oil sands of Pennsylvania seem to converge around 10 per cent as an average. The effective porosity is greater for gas than for oil since the movement of the former through the small openings is not affected by friction to the same extent or by capillarity.

The potentially important gas horizons are to be found in the great succession of Paleozoic rocks which spread over all the State west of the Hudson river with the exception of the Adirondack Highland on the north, where the rocks like those of the Hudson Highlands are of Precambrian age and of igneous or metamorphic character.

Neither the Adirondacks nor the Hudson Highlands hold any possibilities for the production of gas or oil. On the borders of the Adirondacks and for several miles outward the lower Paleozoic sediments which overlap on the older crystallines do not attain sufficient thickness to store any large supplies of gas. West of the Black river and south of the Mohawk, however, the sedimentary succession rapidly thickens with the appearance of new and higher formations.

Thus the Precambrian basement in the vicinity of Pulaski, Oswego

county, at the east end of Lake Ontario, is reached at 1425 feet depth. At Central Square, farther south, it lies 2415 feet from the surface. At Utica granite is found at 1855 feet depth. In Onondaga county the basement is 3000 feet or more below the surface, as shown by deep wells at Baldwinsville and Jordan.

The thickness of the Paleozoic section in western New York normally increases from north to south at the rate of from 50 to 100 feet to the mile, with allowance for the variations in the elevation above sea level. This is the indicated dip of the Medina formation as taken from records of a large number of wells distributed over the central section to the south of the line of outcrop which lies along the shore of Lake Ontario from Oswego county to the Niagara river.

Main gas horizons. Natural gas has been found over a wide range of the Paleozoic formations that extend in general from the Potsdam sandstone in the Cambrian to the higher Devonian strata represented by the Chemung sandstone, and also probably includes the basal Carboniferous which occupies a limited area in the extreme southwestern part of the State as a northerly extension of the main Appalachian belt. The largest and more permanent flows, however, come from a few stratigraphic horizons, which are here given in order of succession.

GAS-BEARING STRATA	DEVELOPED POOLS, BY COUNTIES
Chemung and Portage sandstones.....	Allegany, Cattaraugus, Chautauqua, Steuben
Marcellus shale.....	Cattaraugus, Erie, Livingston, Ontario
Onondaga limestone.....	Cattaraugus, Erie
Salina waterlime.....	Cattaraugus, Erie
Medina sandstone.....	Cattaraugus, Chautauqua, Erie, Genesee, Livingston, Monroe, Ontario, Wyoming
Trenton limestone.....	Niagara, Onondaga, Oswego, Oneida

The Chemung and Portage are here classed together, as the horizons that yield the gas have not been well defined as yet. Some wells are known to give flows from both formations. In the southern section of Allegany and Cattaraugus counties the productive strata may include Carboniferous representatives, as in certain districts there is a considerable thickness of these rocks above the Chemung and the boundary can not be established from the well records. In parts of Steuben, Allegany and Cattaraugus counties both oil and gas are obtained within the Upper Devonian strata. In the

northern part of Cattaraugus county and central and northern Chautauqua county productive pools have been encountered in the last few years by deep wells bottomed some 1500 feet or more below the Chemung and Portage horizons. The lower gas-bearing strata are assigned with some degree of probability to the Medina formation. The thickness of the Portage strata in western New York is placed by Clarke and Luther at about 900 feet. On the line of the Seneca river it is 888 feet; and at Seneca lake 1122 feet. The Chemung formation, according to the same authorities, is over 1000 feet. Along the Genesee the measured thickness is given as 1015 feet; at Seneca lake, 1050 feet. In the Cayuga Lake region and farther east to the Chenango valley the strata are even somewhat thicker than indicated for the western sections.

The Marcellus beds are a black, soft bituminous shale that lies above the Onondaga limestone in the area west of Schoharie county, marking the beginning of the extensive shale accumulation that continued through the Hamilton period. The black shale is 40 to 60 feet thick in the natural gas region and is a well-marked horizon that commonly yields pockets of gas and occasionally more persistent flows. It is likely the original source of much of the gas occurring in the Onondaga limestone. The shale constitutes an element of some difficulty and even danger to the exploration for salt in the western part of the State, particularly in the excavation of shafts, owing to the gas flows that are frequently encountered at this horizon and that are sometimes violent when first tapped.

The Onondaga limestone and the Bertie waterlime, the latter a part of the Salina series, constitute a subsidiary gas zone in parts of Cattaraugus and Erie counties. The two form practically a single horizon, so far as this area is concerned, for they are contiguous formations or at most separated by a thin sandstone layer (Oriskany). From the drill records it is frequently impossible to distinguish between the two limestones. Most of the gas in the Onondaga seems to occur in the "bull-head" stratum near the base which is more porous and permeable than the Corniferous beds above. The largest flows from these formations have been reported in the district in southern Erie and within Cattaraugus county where the wells are 1500 to 1700 feet deep.

The Medina sandstone represents the most widespread natural gas zone in the State. Its importance did not gain recognition until quite recently but is now fully appreciated by drillers who are actively engaged in the search for new gas supplies in this horizon. The first large district in this sandstone was opened in Erie county

in the townships east and southeast of Buffalo during the few years succeeding 1899. Then followed the discoveries along the lake belt in Chautauqua county where shallow wells in the Devonian had long been in use, the opening of additional wells in central and southern Erie county, the development of the Pavilion field in southeastern Genesee county and of other fields in the adjoining territory. There are doubtless important supplies in the Medina yet to be tapped, for the sandstone underlies an extensive area. Its outcrop extends from the vicinity of Oneida lake in central New York west for 150 miles to the Niagara river which it crosses and continues into Canada. Its extension on the dip, which is to the south, has been followed in places as far as 25 to 50 miles from the outcrop, and no doubt it underlies all of western New York between the outcrop and the Pennsylvania line. The inclination averages around 40 feet to the mile for the first several miles south, but seems to flatten in the middle part of the State so that the depth to the Medina in the southern tier of counties is less than would be anticipated in view of the dip near the outcrop. The Medina sandstone represents only a part of the entire formation which includes a great mass of red and gray shales with their sandy layers that measures fully 1000 feet thick in western New York. The sandstone occurs above the main shale beds through a vertical range of 100 to 150 feet, terminated at the base by a 25-foot bed of gray sandstone (Whirlpool sandstone). Below the main shales at the base of the Medina occurs the Oswego sandstone, 75 feet thick in western New York. This is also a possible horizon for natural gas. Most of the pools in the Medina proper seem to be contained in the middle and lower beds of sandstone and above the thick shales.

The Trenton limestone, as the name is used in the natural gas field, includes the assemblage of calcareous beds that lies just below the Cincinnati shales and is composed of the Lowville, Black River and Trenton stratigraphic units. The Trenton is developed in the Champlain valley, along the Mohawk river to the south of the Adirondacks, and in the Black River valley from which a broad belt reaches west to the St Lawrence river and Lake Ontario. It does not outcrop in western New York, but is exposed on the north shore of Lake Ontario under which the beds extend to the south side so as to be encountered in wells all the way from Oswego county to the Niagara river. In this section a dip of about 40 feet to the mile is to be expected. On the west end in Niagara and Erie counties the Trenton is credited by Bishop with a thickness of 720 feet, mostly limestone. No important gas pools have been

encountered within the beds in that section. The most westerly point at which any considerable flow has been met is at Baldwinsville, Onondaga county, where the top of the limestone lies 2240 to 2400 feet from the surface and is covered by 500 feet of Pulaski and Utica shales. In Oswego county small but persistent wells have been opened in the Trenton at Fulton, Pulaski and Lacona where the first was drilled about 30 years ago. In this region the Trenton aggregates 600 feet or over and is overlain by an equal thickness of shale. Through the Mohawk valley the Trenton occurs in more or less broken areas, with the outcrop lying close to the Precambrian border; the character of the formation also changes, shales largely superseding the limestones. In Oneida county, however, it is still undisturbed and appears in considerable thickness in the wells at Rome and Utica. Gas flows that developed high initial pressure have been found at Rome but they did not prove persistent and no production has been recorded from them for several years. The top of the limestone was found at 660 feet and the thickness was a little over 400 feet. At Utica the limestone is 360 feet thick. In the lower Mohawk the Trenton is largely a shale formation being represented chiefly by 700 feet of black shales (Canajoharie shales) of lower Trenton age.

NOTES ON FIELD DEVELOPMENTS

The following pages summarize briefly the present stage of development of the natural gas industry in the principal districts which are listed according to the counties of their occurrence. The information has been obtained by correspondence with the larger producers and distributing companies, and from individual cooperation of those engaged in field exploration. Among the latter Mr D. W. Williams, formerly field expert for the Dominion Natural Gas Co., Buffalo, has been particularly helpful. For the records of the earlier developments preceding 1900, the reports by I. P. Bishop and Edward Orton, listed at the end of this chapter, have been freely used.

Allegany county. The gas belt lies in the southern townships where the pools are found in sandstones that are probably to be correlated with the productive oil and gas sands of the Bradford field of Pennsylvania. The horizon is probably Chemung, but may extend locally up into the Lower Carboniferous. Many of the wells yield both oil and gas, and some of the latter is employed at the well mouth for operating the pump. The excess of production over the requirements for fuel and light at the source is sold to

distributing companies who operate pipe-lines in this district. Among these are the Empire Gas and Fuel Co., the Producers Gas Co. and the Iroquois Natural Gas Co.

Well records for southern Allegany county are given under the head of petroleum elsewhere in this report.

In central and northern Allegany county exploration for gas and oil has been carried on more or less extensively but without the discovery so far of any extensive pools. It would appear that the productive sands in the Devonian do not extend much north of the Clarksville—Wirt—Andover town lines. However, there are possible deeper horizons for gas in the Onondaga or Medina which have been found to contain pools in Cattaraugus county to the west. Only a few deep wells in the territory are on record.

Hume well. A deep well in the town of Hume, northern Allegany county, was drilled in 1899 on the Buel farm, 1 mile west of Hume post office. The following record is reported by Bishop.¹ The well was practically dry.

Soil	35 feet
Shale	260
Shells and slate	280
Shale	401
Wet sand	402
Salt water	415
Shale	765
Gray sand	785
Shale	800
Gray sand, a little gas and oil	1 055
Shale with some gas	1 155
Soft brown shale	1 177
Soft sand with gas	1 192
Soft sand	1 227
Sand with shale and show of oil	1 234
Brown shale	1 550
Light colored shale	1 700
Very dark shale	1 890
Hard flint rock	1 925
Light colored shale	1 945
Hard flint	1 960
Soft light colored shale	1 980
Flinty with shells, very hard	2 002
Dark shale	2 126
Very dark shale	2 174
White shale	2 380
Dark shale with occasional hard shells	2 550
Shale and shells	2 750
Hard gray and brown sand or limestone	2 840
Clear rock salt	2 900
Soft blue and red shale	3 015
Blue and red shale	3 326

Canaseraga well. A test well at Canaseraga in the town of Burns

¹ N. Y. State Mus. Annual Rep't 53, v. 1, p. 1108.

was drilled in 1908-9 by J. E. Dunnigan, Friendship, N. Y., who supplied the following details. It showed a little gas.

Gray sand, some gas and oil at	275 feet
Second gas streak in sand at	400
Chocolate sand with a little gas and oil at	975
Black and brown shale chiefly to	2 650
Hard limestone at	2 650
Rock salt (65 ft.) at	3 050
Blue shale at	3 115
Blue shale to bottom at	3 200

The limestone found at 2650 feet was doubtless the Onondaga but the top was probably reached before that depth, as the normal distance between the salt and the first Onondaga beds in the western areas is 500 to 600 feet.

Cattaraugus county. As in Allegany county, the principal gas pools so far developed lie in the southern townships and are associated with the oil-bearing strata in the higher Devonian formations, an extension of the Pennsylvania oil and gas field. The productive district covers parts of Olean, Allegany, Carrollton, Redhouse and Humphrey townships. The reservoirs occur in sandstones that lie at several levels from 500 to 1600 feet depth. One of the horizons is regarded by well drillers as the equivalent of the Bradford sand. The first oil well was drilled in 1864 and the county was a large producer for a time, but the wells now have to be pumped and the average output is only a fraction of a barrel a day. The surplus gas is sold to the distributing companies who have pipe-lines to the larger consuming cities. Further details of wells will be found under the head of petroleum.

Exploration for gas in northern Cattaraugus county has shown the presence of deep horizons in what are regarded as Marcellus, Onondaga and Medina formations. The most successful wells are in the vicinity of Gowanda and between there and Cattaraugus creek and are thus partly in Erie county. The first important well, according to Bishop, was drilled in 1898 near the tannery of Grenssler and Fisher and yielded a flow estimated at 7,000,000 feet a day. The horizon is referred to the Marcellus shale, 25 feet above the Onondaga. A second well put down nearby showed a good flow from the Corniferous beds of the Onondaga. The Medina sandstone has been tapped in certain deep wells within the Cattaraugus reservation, west of Gowanda.

Vinton well, Gowanda. This well is recorded by Bishop as drilled

by J. D. Rickerson and completed March 23, 1883. It was put down at Gowanda on the Cattaraugus county side.

Salt water at	250 feet
Gas and oil at	458
Oil at	904
Gas at	1 006
Top of Corniferous at	1 580
Water at	1 580
Bottom of well	1 700

McMillan well, Gowanda. This hole was drilled near the cemetery in Gowanda about 1899 and is reported by Bishop who obtained the record from Mr Michael McIntyre of the Gowanda Natural Gas Co.

Drift	20 feet
Casing	196
Small flow of gas at	615
Second gas at	1 110
Top of Corniferous (Corniferous 185-190 feet thick) at.....	1 410
Show of oil at	1 600
Top of Niagara at	1 680
Bottom of well	1 720

Versailles wells. These are in the extreme northwestern corner of Cattaraugus county on the Erie county border. They are quoted from Bishop's records.

<i>Well No. 1</i>		<i>Well No. 2</i>	
Rock at	15 feet	Rock at	42 feet
Casing	185	Casing	199
Top of Corniferous at	1 075	Top of Corniferous	1 241
Bottom of Corniferous at	1 275	Bottom of well	1 543
Bottom of well	1 383		

In well no. 1 some gas was found at 190 feet in shale.

In no. 2 a small flow was tapped at 940 feet in shale.

Chautauqua county. The first gas wells in the State were drilled in this county. The supplies were obtained by shallow wells bottomed in sandstones of the Chemung and Portage formations which together occupy the surface from the Erie county line to the Pennsylvania boundary. Many of the borings were only 100 to 150 feet deep and the deepest about 500 feet. The pools were not large, but they showed a fair degree of persistency and were scattered over the lake shore belt from Silver Creek southwest to the State line. Many afforded convenient and easily controlled supplies, but scarcely sufficient for more than local use, most of the wells in fact supplying only one or two families each with light and fuel. The aggregate production, thus, was not large. The principal towns within this natural gas belt are Silver Creek, Dunkirk, Fredonia, Brocton, Westfield, Mayville and Ripley.

In 1886 a project for exploring the deeper formations in this region was formed by citizens of Fredonia. The incentive thereto seems to have been supplied by the contemporaneous developments in the gas fields of Ohio where large wells were being brought in at depths of 1000 feet or more. A well was started in that year and completed in the summer of 1887 at a depth of over 2500 feet. The test was unsuccessful, further than it revealed a small flow of gas at 2100 feet in sandstone which was regarded as the Medina. Thereafter for many years little effort was made to search for gas in the lower formations of the county.

About 1903 interest seems to have revived, as a result perhaps of the success attained in locating pools in the Medina of Erie county. Silver Creek was the site of the new wells, and by 1904 several good producers had been brought in by the South Shore Gas Co. and the Silver Creek Gas & Improvement Co. The main flow was found in the Medina at 1700 feet. The wells have been persistent and the supplies were later increased by additional borings. In 1904 the Brocton Gas & Fuel Co. put down two wells at Brocton which penetrated the Medina at 2225 feet depth. One of the latter yielded a small flow from that horizon and the other gave a little sulphurous gas from higher up in the Devonian formations.

The Frost Gas Co. of Fredonia shortly after undertook explorations in the town of Sheridan and the Welch company in the town of Westfield. These were also fairly successful. A well in the village of Westfield, as reported by the latter company, developed a flow at 2355 feet in white sandstone.

Within the last 10 years a large number of deep wells have been put down in the lake shore belt of Chautauqua county and this has become one of the important producing districts of the State. The flow comes from the upper 150 feet of the Medina formation in the red and gray sandstones.

Well on Miner farm, Sheridan. This well, situated on the farm of H. S. and M. F. Miner, was drilled between December 29, 1917 and February 19, 1918, for the South Shore Gas Co., who has kindly supplied the record.

Surface materials	22 feet
White and brown shale	955
Flint	1 175
White lime	1 600
Niagara limestone	1 812
White shale	1 890
Clinton	1 915
Red Medina	1 995
Gray Medina	2 015
White shale	2 030
White Medina	2 044
Red shale to bottom at	2 061

A little gas was found at 1945 feet or 30 feet below the top of the red Medina sandstone.

Well on H. S. Miner farm, Sheridan. The well was drilled in March and April 1918 for the South Shore Natural Gas Co. which supplied the record. A good flow of gas was encountered at 2101 feet in the white Medina sandstone. The Niagara horizon was marked by influx of "black water."

Surface materials	22 feet
White and brown shale	990
Flint	1 205
White lime	1 645
Niagara limestone	1 846
White shale	1 933
Clinton	1 953
Red Medina	2 033
Gray Medina	2 048
White shale	2 084
White Medina at bottom at	2 101

Well on Franklin farm, Hanover. The site of the well is on the R. Franklin farm, town of Hanover. Hole drilled for the South Shore Gas Co. from which the record has been obtained. Well bottomed April 4, 1918. Small flow of gas at 2300 feet. The Niagara horizon was indicated by the usual black or sulphurous water.

Surface materials	14 feet
White and brown shale	1 296
Flint	1 501
White lime	1 896
Niagara limestone	2 125
White shale	2 210
Clinton	2 240
Red Medina	2 316
Gray Medina	2 334
White shale	2 354
White Medina	2 374
Red shale to bottom at	2 386

Erie county. The natural gas area of Erie county is larger and more important than of any other county of the State. Successful wells have been located in all parts of the county if not in every township, although of course they draw their supplies from many different pools that altogether underlie only a small portion of the whole surface. The range of gas territory may be said to extend from Niagara county on the north to the Cattaraugus-Chautauqua border on the south and from Lake Erie and the Niagara river to the eastern limits of the county. For the last 15 years, that is

within the more active period of exploration and development of the gas fields, Erie county has held a leading place in the industry.

The source of its importance can be ascribed to the Medina sandstone which here seems to offer especially favorable conditions for the storage of natural gas. The whole county is underlain by the Medina formation which has its outcrop farther north in Niagara county and is reached at depths increasing steadily toward the south in accordance with the dip of the beds which is at the rate of about 40 to 50 feet to the mile in that direction. The upper 100 to 140 feet of the formation comprises the main sandstone beds within which the gas is commonly stored. Below is a body of red and gray shales with their sandstone layers, 900 feet or more thick, also a part of the Medina but usually barren of gas. Well records indicate usually a division of the sandstone into red and gray beds, the former occurring above and measuring about 70 to 80 feet thick, while the gray lies directly below or is separated from the red by a few feet of shale. The gray sandstone averages perhaps 25 feet thick. A second bed of the gray is occasionally indicated in the records and is referred to by some drillers as "white Medina."

The Medina marks practically the lowest horizon at which natural gas has been found in quantity in this region. A few wells have been drilled into the lower formations, as far as the Trenton limestone, without encountering additional pools.

In the higher strata gas may be found locally in some quantity. The Clinton shales have been found to contain pockets and the Lockport dolomite often affords limited quantities of sulphurous gas and water, which serve to establish the horizon where they occur. The most favorable horizons above the Medina are the waterlime in the Salina, the Onondaga limestone and the Marcellus shale. The Onondaga limestone and the underlying waterlime bed, according to Bishop, were probably the source of the gas in the Zoar field in southern Erie county which for a time was quite productive and probably had the record well that has so far been drilled in the State with an estimated initial flow of 25 to 30 million cubic feet a day.

Bishop¹ has compiled the following estimates of the thickness of strata for the section from Lake Ontario to Cattaraugus creek.

¹ The Structural and Economic Geology of Erie County. N. Y. State Mus. Rep't 49, pt 2, 1895.

Some changes have been made in the terminology, but none in the estimates as made by this authority.

Portage shales and sandstones	1 541 feet
Genesee shale	25
Hamilton and Marcellus shales	287
Onondaga limestones	108
Salina waterlime	60
Salina shales	386
Niagara limestone, including 72 feet of shale below	319
Clinton	27
Medina sandstone	109
Medina shales, Oswego sandstone, and Cincinnati beds	1 869
Trenton limestone	720
Calcliferous	110
Total	5 561

The section probably falls short by 100 to 200 feet of the whole range from the top of the Portage to the Precambrian basement, for the Calcliferous is not fully revealed in the wells on which the above estimate is founded and also the Portage may be a little thicker than indicated.

Among the first successful wells drilled in Erie county were those located within the city of Buffalo. According to Bishop the Buffalo Cement Co. instituted the earliest systematic search for gas within the city limits by drilling on its property situated near the Main street crossing of the New York Central Belt Line. Its first well was put down in 1883 to a depth of 452 feet, and the second in the following year, both showing only a small flow. A third well in 1887 gave a good flow and encouraged the company to continue drilling operations, so that shortly several productive wells were opened. Active work was then undertaken by individuals and companies, and the distribution of the gas for household and industrial use provided for by the laying of municipal pipe-lines. In 1891 drilling was extended into the town of West Seneca, just south of the city line, and a large increment to the supply was soon obtained from that section. All of the commercial wells in Buffalo and vicinity had been absorbed by 1895 into the Buffalo Natural Gas Co. The district as then developed included Buffalo, West Seneca and a little territory on the west side of the Niagara river, in Ontario, Canada. Records of many of the wells are given in Bishop's paper,¹ "The Structural and Economic Geology of Erie County." One or two records are here quoted from that article.

¹ N. Y. State Mus. 49th Ann. Rep't, pt 2, 1895.

Well No. 2, Buffalo Cement Co. Location is given as near Main street and New York Central Belt Line, Buffalo. A fair quantity of gas at 452 feet; salt water at 555 feet.

Shale and cement rock	25 feet
Fairly pure cement rock	30
Shale and cement rock in thin streaks	43
Pure white gypsum	47
Shale	49
White gypsum	61
Shale	62
White gypsum	66
Shale and gypsum, mottled	73
Drab-colored shale with several layers of white gypsum	131
Dark-colored limestone	133
Shale and limestone	137
Dark-colored compact shale	140
Gypsum and shale, mottled and in streaks	720
Limestone	725
Soft red shale	760
White solid quartzose sandstone	785
Soft red shale	1 305

Well on John M. Fick farm, West Seneca.

Drive pipe	26 feet
Casing	123
Flint at	318
Bottom of flint at	509
Niagara at	890
Sulphur gas at	1 020
Water and gas at	1 060
Through water and gas to	1 132
Clinton at	1 200
Medina sand at	1 223
Bottom Medina sand at	1 308
Gas sand at	1 326
Through gas sand	1 337
Pocket to	1 413

Well on Elbert More farm, Spring Brook.

Soil	17 feet
Fresh water at	47
Casing	110
Shale	435
Flint	600
Niagara limestone at	935
Sulphur gas at	1 100
Sulphur water at	1 165
Shale (60 feet) at	1 245
Clinton at	1 325
Top of Medina at	1 433
Gas sand at	1 436
Gas sand at	1 438
Bottom gas sand (white) at	1 460
Red rock (800 feet) to	2 260
Black shale (900 feet) to Trenton	3 100

North of Buffalo in the towns of Tonawanda and Amherst and in the proximate portion of Niagara county are a number of small wells, of which the most are grouped in the southeastern part of the town of Tonawanda and in the vicinity of Getzville, town of Amherst.

Well on Mrs Eva Fries farm, Tonawanda. Well drilled in March and April 1918 by North Buffalo Natural Gas Co. Gas with a moderate flow was found at 561 feet in the Clinton formation. No gas in the Medina.

Surface	274 feet
Niagara	474
Shale, soft gray	549
Clinton	579
Medina, red sandstone	648
Medina, gray sandstone	682
Shale	685

The largest district of Erie county in regard to area and number of productive wells lies in the townships of Clarence, Newstead, Lancaster, Alden, Marilla and Elma, east and northeast of Buffalo. The proved territory embraces a surface of about 10 miles long east and west and 8 miles wide; the same gas belt may be traced, however, beyond the limits of Erie county into the adjoining section of Genesee county, so that the area is even larger than indicated by these figures. The first wells in the district were put down some 25 years ago, but there was little activity in the exploration before 1900, when the possible importance of the field began to be realized. There are no extraordinary pools within the area that compare in pressure or yield with the records that have been reported from some of the great natural gas districts of the country. The wells mostly show a moderate flow, a few hundred thousand cubic feet a day, perhaps, as the usual upper limit, but they have proved profitable by reason of their consistent nature and the favorable combination of conditions for exploiting and selling the output. There are over 200 wells in the district. The gas comes from the lower third of the Medina sandstone, which measures about 110 feet thick in this part and is encountered at depths of 1000 to 1200 feet in most wells, measured to the top of the first bed. A contour map of the sandstone, based on well data and prepared by the geological staff of the Dominion Natural Gas Co. shows that the strata are slightly folded along a north-south axis across the dip. The most marked fold is an anticline whose summit lies just west of a line drawn between Mill Grove and Alden Center in the town of Alden. There

is a considerable number of good wells situated along the anticline, though the productive pools occur along the flanks with nearly equal profusion. Minor folds are present to the east and west of the main anticline, the dip of the strata follows about the average rate of 50 feet to the mile. One or two typical well logs will serve to indicate the stratigraphic relations.

Well on Charles Schlung farm, Lancaster. The well was drilled for the Akron Natural Gas Co. in 1913 by C. C. Rose. Record supplied by the Dominion Natural Gas Co., Buffalo. Volume 210,000 cubic feet. The flow comes from 1230 to 1240 feet depth.

Flint	200-360 feet
Niagara	810-1 010
Clinton at	1 122
Medina	1 140-1 250

Well on the Hoppe farm, Marilla. The well was drilled by C. C. Rose for the Akron Natural Gas Co. in 1910. Volume 150,000 cubic feet at 1350 feet depth.

Flint	320-470 feet
Niagara	942-1 142
Clinton at	1 220
Medina sandstone	1 257-1 369

Well on the Emil Hinsken farm, Alden. Put down for the Akron Natural Gas Co. in 1912. Volume of flow 800,000 cubic feet at 1286 feet depth. Sulphur gas at 965 feet; water at 1000 feet.

Flint	265-425 feet
Niagara	875-1 075
Clinton at	1 184
Medina sandstone	1 208-1 316
Bottom at	1 379

Deep well, Elma. The record of this well, drilled by James Stearns in 1903, was supplied by H. O. Wagner of Caledonia, N. Y.

Flint (170 feet) at	225 feet
Niagara at	845
Black water at	945
Niagara, bottom at	1 025
Clinton (20 feet) at	1 130
Medina sandstone (115 feet) at	1 150
Red shale (515 feet) at	1 265
Little gas at	1 900
Oswego sandstone (70 feet) at	2 230
Black shale at	2 360
Trenton limestone (750 feet) at	3 160
Potsdam at	3 986

Deep well, Depew. This record, taken from Bishop's "Structural and Economic Geology of Erie County," supplies an interesting parallel with the preceding one.

Drift to	34 feet
Flint at	34
Niagara (200 feet) at	594
Shales (60 feet) at	794
Clinton (30 feet) at	854
Red Medina sandstone (90 feet) at	884
White Medina sandstone (12 feet) at	974
Red shale (1164 feet) at	986
Oswego sandstone (75 feet) at	2 150
Shale (630 feet) at	2 225
Trenton (720 feet) at	2 855
Dark gray sandstone (110 feet) at	3 575
Bottom at	3 685

A small flow of gas was found at 1100 feet in the Medina formation.

One of the latest developments in the Erie county gas field has been the discovery of the Orchard Park pool in the town of East Hamburg, where a small area of high pressure gas was tapped in 1912. About twenty wells are located in the area. At first the flow was exceptionally large for pools in the Medina, but the yield fell off rapidly after the first few months. The wells are about 1700 feet deep. The output is handled by the Orchard Park Oil & Gas Co.

In the town of Brant, in the southwestern corner of Erie county, is an area in which considerable activity has been in progress during the last few years. It covers a part of the Cattaraugus Indian reservation, and some 40 wells have been put down within the reservation or along the border. The gas comes from the Medina at 1700 to 1800 feet depth.

On the border of Erie and Cattaraugus counties between Gowanda and Springville lies the Zoar district which was developed in the years 1888-95 and for a time was a large producer. The Kerr well, drilled in 1888 by Michael McIntyre of Gowanda, was probably the largest that had been drilled in the State up to that time. Its initial flow was estimated at 25 to 30 million cubic feet a day and the pressure forced out the string of tools and threw them 150 feet into the air. The horizon of the gas is referred by Bishop to the Salina waterlime and the lower part of the Onondaga limestone. The usual depth was about 2000 feet. In recent years attention has been given to the underlying Medina horizon, which is found at about 3300 feet, with some success.

Kerr well, Zoar. Drilled in 1888 by Michael McIntyre of

Gowanda. Record given by Bishop ("Structural and Economic Geology of Erie County"):

Drift	379 feet
Casing	755
Top of Corniferous	1 725
Gas at	1 885
Bottom	2 150

Richardson well, near Morton's Corners. This locality is in the town of Collins, just north of the Zoar district. The record is taken from "Structural and Economic Geology of Erie county" by Bishop.

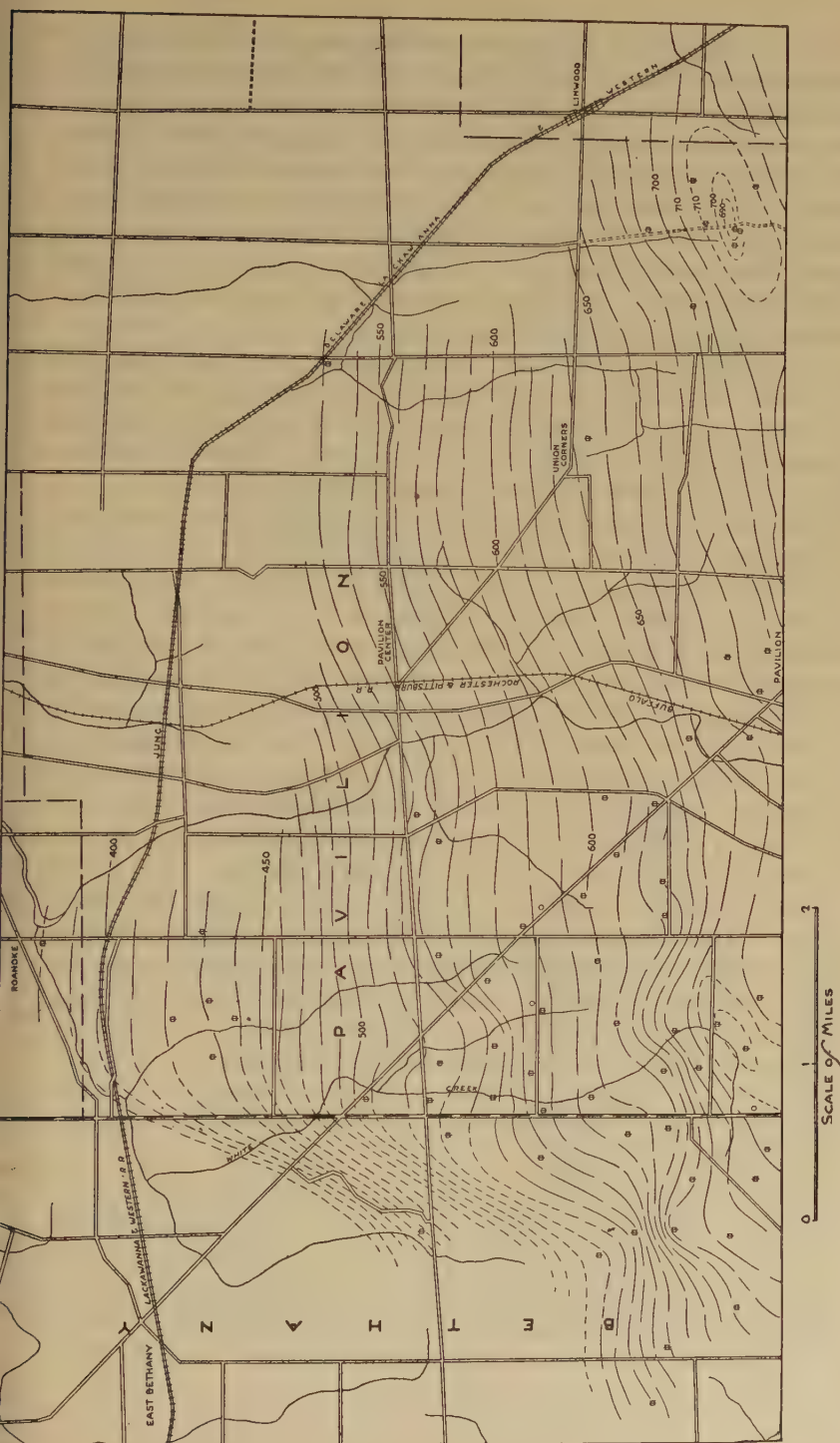
Drift	80 feet
Casing	435
Top of Corniferous at	1 925
Small flow of gas at	2 195
Salt water at	2 675
Salt water, chocolate colored sand at	2 785
Through limestone and shale at	2 815
Red Medina at	2 815
Through White Medina at	2 990
Red shale at	2 990
Bottom (red shale) at	3 303

Genesee county. A small gas field occurs in the southwestern corner of Genesee county in the town of Darien. It might be considered as an extension of the eastern Erie county field although it is separated from the latter by a stretch of 3 miles in which no productive pools have been found. About 15 wells have been drilled, most of them in the area south and southwest of Corfu Station on the New York Central Railroad. The first holes were put down about 20 years ago. The gas occurs in the Medina sandstone at about the same depth and under similar conditions as in the Alden section of Erie county.

The main producer of the county is the Pavilion field which came under development in 1906 and since has ranked as one of the most important fields for its size in the State. Mr W. P. Randall, formerly engineer for the Pavilion Natural Gas Co., has supplied the following details in regard to the occurrence of the gas.¹

The Pavilion field lies south of the Roanoke district in the southeast corner of Genesee county. Its boundaries are defined approximately by a line running from the southern boundary of Genesee county northerly to Bethlehem Center, thence easterly along the Telephone road through Pavilion Center to the east boundary of Genesee county, thence south on said boundary to the corner of Genesee county and thence west to the point of beginning. It comprises an area 3 miles wide north and south and 9 miles long

¹ See N. Y. State Mus. Bul. 174, 1914, p. 58-59.



Map of the Pavilion natural gas field, from surveys of the Dominion Natural Gas Co., showing contours of the Medina gas-bearing strata

east and west. The gas is distributed by two companies, the New York Central Gas Co., with pipes running to Batavia, Attica, Corfu, and other towns in that vicinity, and the Pavilion Natural Gas Co., which supplies Mumford, Caledonia, Le Roy, Pavilion, Warsaw, Perry, Mount Morris, Moscow and smaller places along the route. New lines are being laid by the latter company to Linwood, York, Greigsville, Retsof, Piffard, Cuylerville, Geneseo and Avon. The trunk lines convey the gas under pressure of from 60 to 125 pounds; reducing stations at the distributing points lower the pressure to the normal required for consumption.

The gas is dry, nearly pure marsh gas with less than 8 per cent of other ingredients. The pressure in the original wells was 500 pounds a square inch and has shown little diminution. Along the eastern boundary of the field and near Linwood, wells of from five to seven million cubic feet daily capacity have been drilled.

The field lies along the outcrop of the Genesee shale which is at an elevation of about 900 feet above tide. The gas flow is found at intervals in the last 30 feet of the Medina sandstone. The succession of strata explored by the wells conforms to the normal order as given in the reports of the New York State Museum, but in the western boundary of the field and near Lindon the Niagara is disturbed so as to make the drilling of straight holes a difficult work. Below such disturbances the Medina gives a very limited flow, and consequently exploration in these places has been discontinued. The Niagara averages about 228 feet thick and black water (sulphurous water from cavities in the dolomite) occurs at about the middle. Below the Niagara comes the Clinton with a thickness up to 15 feet (Wolcott limestone?) and at this point anchor packers are usually placed. The Medina sandstone is a little over 100 feet thick; on the northern and southern borders of the field it gives a limited flow of gas, the largest wells being on the eastern border and around Linwood.

A typical section in the Pavilion field is here given:

Top of flint	475 feet
Bottom of flint	625
Top of salt	1 072
Top of Niagara	1 300
Black water	1 415
Bottom of Niagara	1 500
Top of Medina	1 678
First gas	1 743
Second gas	1 753
Third gas	1 774
Bottom of Medina	1 775
Hole bottomed	1 875

Altitude at mouth of well is about 1000 feet above tide.

Livingston county. There are a number of small pools in the northern part of the county, mainly in the towns of Caledonia, Avon and Lima, which support a few wells each. The flow in the aggregate is small and is employed locally for light and heat, being distributed by the Tri-County Natural Gas Co. to Le Roy, Caledonia, Scottsville and other communities in the vicinity. The horizon is the Medina sandstone which lies at depths below 1200 feet in most of the wells.

Well on the John C. Mitchell farm, Caledonia. The well is located 3 miles south of Caledonia village and was drilled in 1913. A small flow of gas was found at 1309 feet. The record has been contributed by H. O. Wagner, Caledonia.

Earth to	31 feet
Flint to	178
Limestone and shale to	482
Salt and cave at	573
Niagara (205 feet) at	870
Clinton (10 feet) at	1 228
Red Medina (61 feet) at	1 248
White Medina (33 feet) at	1 309

Well on the George F. Hudson farm, Moscow. This well, located at Moscow in the town of Leicester, is about 12 miles south of the preceding one. It was drilled for the New York Central Gas Co. Gas was found at 1886 feet.

Flint (130 feet) at	500 feet
Salt (80 feet) at	1 125
Niagara (240 feet) at	1 400
Medina sandstone (75 feet) at	1 826
Bottom of well	1 938

Wyoming county. The productive natural gas section is in the vicinity of Attica, on the border of Genesee county, and a little west of the Pavilion field. The first wells were put down over 20 years ago, and subsequent drilling has not materially enlarged the bounds of the pool. The flow is used at Attica, but of late years has not sufficed for the needs of the village so that the Attica Natural Gas Co. obtains a supply from the Pavilion field. The gas occurs in the Medina sandstone at a depth of 1800 feet or more.

In the eastern part of Wyoming county, at Wyoming village, Warsaw, Rock Glen, Silver Springs and other places many salt wells have been put down. They have not revealed the presence of any considerable gas pools in the formations above the salt, which include the horizons of the Marcellus, Onondaga and Salina waterlime.

Well on the Elon Gore farm, Attica. The well was completed in June 1914 and yielded a fair flow at 1987 feet.

Flint (150 feet) at	840 feet
Niagara (180 feet) at	1 540
Medina (93 feet) at	1 900
Shale at	1 993
Bottom in shale at	2 078

Ontario county. About thirty producing wells are located in the town of West Bloomfield, mainly in the southern part along Gates creek. The gas is in the Medina sandstone which occurs at depths of 1900 to 2000 feet. The measured flow at the outset has ranged up to 1,000,000 cubic feet a day for the larger wells. The first developments took place about 1895 and the output has since been well sustained. The gas is piped by the Ontario Gas Co. to Honeoye Falls. Efforts to enlarge the territory by prospecting along the axis of the main group of wells to the east in the town of East Bloomfield have not been very successful. There have been a few successful wells drilled there, however, as well as in the towns of Bristol and Richmond on the extension of the Medina beds to the south and southeast of the West Bloomfield district.

Well on the John Dailey Farm, West Bloomfield. The well was drilled in 1907 for the Ontario Gas Co. and had an indicated flow of 1,000,000 cubic feet a day. The gas came from 2018 feet depth, 98 feet below the top of the Medina sandstone.

Flint (115 feet) at	525 feet
Bottom of Niagara at	1 825
Clinton at	1 908
Top of Medina at	1 920
Bottom of well	2 064

Well on the Abbey farm, Richmond. Drilled for the Ontario Gas Co., in 1913. A flow of 350,000 cubic feet was reported at 2137 to 2145 feet.

Top of flint at	610 feet
Niagara limestone at	1 600
Clinton at	2 000
Medina sandstone at	2 221

In southern Ontario county is the Naples pool, situated about 1 mile from the village of Naples. The development consists of eight wells, of which the original hole was put down about 1884 as a wildcat oil well by Olean drillers and reached a depth of 1633 feet. The hole was bottomed in the Salina, the last 43 feet being in salt. The other wells were drilled between the years 1900 and 1910 to depths of 1050 to 1150 feet. According to Mr D. D. Luther,

who has contributed these details regarding the development, the principal supply of gas is in the base of the Marcellus shale or in the upper beds of the Onondaga limestone; but pockets occur in the Hamilton shales above the Marcellus horizon. The gas is piped to Naples for heating and light. The wells are owned by Granby and Hemenway who report that the output has fallen off in recent years and increasing difficulties have been met from influx of water.

Monroe county. A pool of natural gas occurs near Churchville in the western part of the county. Its precise location is 3 miles east of Churchville in the town of Riga. Mr Frank B. Barnard, president of the Churchville Oil & Natural Gas Co., which distributes the output, states that the gas occurs in the Medina sandstone and that the flow comes from a zone about 75 feet below the top of the formation which is found at 480 feet. There are about 15 productive wells and the gas is used in Churchville, Bergen and Riga. The occurrence has interest from the shallow depth of the pool, representing probably the minimum depth at which any considerable flow has so far been reported in the Medina formation. The outcrop of the sandstone is only 7 miles distant, directly north of Churchville, at an elevation about 60 feet below the mouth of the wells, as nearly as can be ascertained from the topographic map. This would indicate a dip for the strata at the average rate of 60 feet to the mile.

Well at Brockport. This well was put down many years ago and was reported upon by Prof. C. S. Prosser¹, who gave the following record:

Medina red shale	500 feet
Medina dark red shale	900
Medina very dark red shale	950
Gray and bluish calcareous shale	1 000
Blue shale and sandstone	1 400
Blue compact Trenton limestone	2 000

Yates county. A few wells have been drilled in the vicinity of Rushville on the border of Ontario county. The flow is small and consumed locally. No details are at hand in regard to the horizon of the occurrence.

Seneca county. A number of gas wells were in use at one time for the supply at Seneca Falls. Bishop² mentions that twelve were drilled in the period 1885-97 and at the latter date the supply amounted to 50,000 cubic feet a day. The flow apparently came from different horizons, including the Clinton, Medina and possibly

¹ Proceed. Rochester Acad. Sci. v. 2, p. 91

² N. Y. State Mus. Ann. Rep't 51, v. 2, 1897, p. 12.

the Trenton. One of the well records is here quoted from Bishop's paper.

Drive pipe to limestone	77 feet
Top of salt sand at	305
Bottom of salt sand at	455
Top of big red shale at	485
Bottom of big red shale at	675
Top of Niagara at	710
Top of Clinton at	1 085
Top of Medina at	1 205
Flow of gas at	1 254
Gray Medina at	2 030
Red Medina at	2 140
All gray at	2 175
Gray and black shale at	2 360
Part black shale at	2 400
All black shale at	2 440
Shale and lime mixed at	2 450
All shale at	2 650
Top of Trenton at	3 000
Black shale at	3 200
Limestone at	3 225
Nearly all black shale at	3 240
Crystalline limestone at	3 275
All black shale at	3 400
Limestone with white streaks	3 485
Bottom of well at	3 560

Onondaga county. Natural gas is found at Baldwinsville, north of Syracuse, where it has been in use since 1897. The pool supports about fifteen active wells. The main supply comes from the Trenton formation at depths below 2200 feet but some gas occurs in the Medina and Oswego sandstones at higher levels. Some of the wells were prolific at first, yielding as much as 3,000,000 cubic feet a day; they have been persistent producers, although their flow is now considerably reduced. The conditions of the occurrence were carefully worked out by Prof. Edward Orton. The following is the log of the first well, put down on the Monroe farm just northeast of the village.

Drive pipe	38 feet
Cased	348
White Medina	542
Red Medina	620
Oswego sandstone	1 200
Top of Trenton	2 240
Bottom of well	2 370

A few wells have been drilled in the vicinity of Syracuse, but without any marked success in the discovery of a gas supply. One well, drilled by the Empire Portland Cement Co. on the site of its former works at Warners, reached a depth of 3526 feet, encountering the Trenton limestone at 2700 feet and cutting a sandstone which

was considered to be the Potsdam at 3500 feet. The well yielded a small volume of gas, insufficient to pay for the experiment.

Oswego county. Local pools of natural gas are found at Pulaski, Lacona and Fulton, supporting about fifty wells altogether. The initial developments in this section took place about 1890. Both Pulaski and Lacona are still supplied with gas from the original sources. The wells at Fulton have not proved so persistent producers and have been mostly, if not wholly, abandoned. At Pulaski and Lacona the wells are bottomed at about 1000 feet deep, or 400 to 500 feet in the Trenton limestone of which the top lies at 400 to 600 feet from the well mouth. The full section, as established from borings to the granite basement, is given by Prof. Edward Orton as follows:

Pleistocene	0-96 feet
Pulaski shale	200-250
Utica shale	100-250
Trenton limestone	600
Calcliferous	200
Cambrian limestone and sandstone	35-90
Precambrian granite at	1 400-1 500

Oneida county. Active prospecting for natural gas was carried on in the vicinity of Rome, New York Mills and Utica in the nineties of the last century. The results indicated the presence of gas in small quantities in the Trenton limestone and Cincinnati shales, but no persistent flows were found. The most encouraging indications were encountered in the wells at Rome where the gas when first tapped issued under high pressure and at the rate of 500,000 cubic feet or more a day. The flows, however, quickly subsided so that it was not considered worth while to attempt to distribute the gas for general use. Condensed records of wells in this section are here given.

Well at Rome.

Drift	125 feet
Utica shale	660
Trenton limestone	1 095
Beekmantown and Potsdam	1 295+
Red granite at	1 560

A flow of gas was encountered at 830 feet under pressure equivalent to 6 inches of water, which would indicate 3,500,000 feet a day, but which rapidly declined so that in a few months the measured volume was only a few thousands a day.

Well at Utica. The site of this well, drilled for water, is on the grounds of the Globe Woolen Mills. It was drilled in 1896. A gas flow was encountered at 225 feet but was cased off.

Drive pipe	48 feet
Utica shale	495
Trenton limestone	864
Beekmantown and Potsdam	1 304
Granite to bottom at	1 855+

Gas in other counties. Sporadic attempts have been made to explore for natural gas in the outlying sections, beyond the limits of the known productive areas. Thus, wells have been drilled in most of the counties that lie between the Mohawk river and the Pennsylvania boundary as far east as the Hudson river. In many instances there have been some indications of gas, real or supposed, that supplied an incentive for undertaking the test; very commonly the observation of gas bubbles arising from the bed of a pond or lake has aroused interest, or the tapping of a little gas in a shallow well put down for water supply. The lack of success that has attended such undertakings seems to show that the eastern part of the State is of doubtful value, to say the least, and caution should be exercised in embarking upon any extensive campaign of drilling in this area.

Well on Murphy farm, Catlin, Chemung county. This well was drilled by the Catlin Oil, Gas & Mineral Co. in 1902-3. A small quantity of gas was reported and a trace of oil, as indicated in the following record:

Earth	17 feet
Light gray shale	344
Light slate	350
Brown slate	1 220
First sand, some gas	1 265
Brown shale	1 620
Gray limestone, cherty	1 625
Brown shale	1 670
Salt	1 718½
Second sand, trace of oil	1 763½
Hard cherty limestone	1 766
Red shale, changing to black	2 155
Third sand	2 195
Black soft shale	2 200½

Well at Binghamton, Broome county. The record of this well is taken from a paper by C. S. Prosser in the Bulletin of the Geological Society of America, volume 4, 1893.

Bluish gray argillaceous shale	50 feet
Gray shale, more sandy	150
Bluish argillaceous shale	250
Bluish, finely arenaceous shale	350
Gray and blue shale	550

Gray arenaceous shale, fossiliferous	700 feet
Arenaceous and calcareous shale	800
Blue arenaceous shale	850
Arenaceous red and brown shale	900
Dark gray arenaceous shale	1 000
Bluish argillaceous shale	1 000
Mainly gray to blue arenaceous shale	1 550
Brownish gray finely arenaceous rock	1 950
Light gray arenaceous sandstone	2 000
Bluish argillaceous shale	2 050
Fine dark blue rock (Tully limestone?)	2 250
Blackish argillaceous shale (Hamilton?)	2 300
Grayish argillaceous shale	2 350
Gray argillaceous, slightly sandy shale	2 400
Gray sandstone and blue shale	2 550
Gray and blue shales and sandstones	2 600
Gray sandy rock, fossil fragments	3 000
Dark gray sandy rock to bottom at	3 117

Well at Norwich, Chenango county. The record is from the same source as the preceding. Altitude of mouth of well approximately 1000 feet.

Dark gray arenaceous shale	75 feet
Mostly argillaceous shale (Portage)	125
Bluish gray sandy rock (Portage)	175
Pine gray sandstone (Sherburne)	250
Dark gray and greenish shales, gas at 384 feet (base of Portage)	450
Bluish argillaceous shale (Hamilton)	620
Gray calcareous shale (Hamilton)	685
Gray calcareous shale (gas pocket)	875
Dark gray arenaceous shale, fossiliferous	1 460
Dark gray shales	2 050
Dark blue to black shales (base of Hamilton)	2 235
Very dark shale (Marcellus?)	2 234

Well on Beckwith farm, Cincinnatus, Cortland county. The record of the well was communicated to this office by L. Nusbaum.

Gravel	40 feet
Quicksand	70
Blue limestone	110
Pink rock	200
Lime shells	254
Casing to	275
Hard shells	290
Light slate (gas pocket)	330
Hard limestone	395
Black sandy rock at	395
Salt water at	410
Bottom of sand at	435
Brown sand	580
Salt water and gas	590
Slate	636
Light slate	700
Brown shale	730
Light slate	890
Hard shelly rock	905

Dark slate	928 feet
Hard limestone	970
Dark slate	980
Hard brown sandstone	1 120
Light slate	1 168
Brown shale	1 440
Hard sandstone	1 465
Brown shale	1 600
Hard sandstone	1 620
Soft brown shale	1 800

Well near Auburn, Cayuga county. This deep well, located $1\frac{1}{2}$ miles north of Auburn, is reported by C. S. Prosser in *American Geologist*, volume 25, 1900. The condensed general section taken from the well log follows.

Salina green and gray shales	1 055 feet
Niagara limestone and shales	1 380
Clinton shales (iron ore?)	1 505
Medina sandstone (some gas)	2 115
Medina shale with some sandstone	1 600
Oswego sandstone	2 770
Pulaski and Utica shales	3 327
Trenton limestone	3 570

Well at Ilion, Herkimer county. The site of this well was on the grounds of the Remington Typewriter Co. and close to the Erie canal. It was put down for gas, of which small amounts were found at 800, 950 and 1003 feet in the Calciferous sandrock. The following is a condensed record, based on the log published by C. S. Prosser (*American Geologist*, volume 25, 1900).

Drift	195 feet
Utica shale	475
Trenton limestone	580
Lowville limestone (lower part perhaps Calciferous)	630
Calciferous sandrock	1 105
Precambrian gneiss to bottom	1 135

Well at Altamont, Albany county. A deep well for gas was drilled in 1886 at Altamont (formerly Knowersville) one-quarter of a mile south of the railroad station, and at an elevation of 510 feet above sea level. No detailed record of the boring was kept, but it is reported by C. A. Ashburner (see reference at end of article) that shales (Hudson River) were encountered to a depth of 2880 feet, at which point limestone (Trenton) was struck and penetrated for 132 feet to the bottom of the well at 3012 feet. A gas pocket with 40 pounds pressure was opened at 497 feet.

Well on Finch farm, Knox, Albany county. This boring was about $4\frac{1}{2}$ miles from the Altamont well in a direction a little west of north, at an elevation 1155 feet above sea level. It penetrated gray and

black slates with thin sandstone beds to a depth of 2200 feet, passing the horizon of the gas in the Altamont well at 1000 to 1050 feet, according to Ashburner. No gas was found.

Well in Cairo township, Greene county. A deep well for gas was put down in 1886 in the town of Cairo, Greene county, about $3\frac{1}{2}$ miles southwest of Cairo village. It was located by Pennsylvania oil operators, who it is said expected to tap the Trenton limestone, although the formations in the vicinity are well up in the Devonian. Drilling ceased at 2200 feet after encountering nothing more than flagstones and shales of the Catskill series, without any gas. A flow of salt water entered the well at 610 feet and filled the bore to a height of 300 feet in 26 hours.

References

- Ashburner, C. A. Petroleum and Natural Gas in New York State. Amer. Inst. Min. Eng. Trans., vol 16, 1888
- Bishop, I. P. Petroleum and Natural Gas in Western New York. N. Y. State Mus. Ann. Rep't 51, v. 2, 1899
- Oil and Gas in Southwestern New York. N. Y. State Mus. Ann. Rep't 53, v. 1, 1901
- Orton, Edward. Petroleum and Natural Gas in New York. N. Y. State Mus. Bul. 30, 1899

PEAT

Peat bogs are present in most parts of the State and altogether cover an extensive area. The most reliable estimates place the swamp lands at about 5 per cent of the entire surface, which is 49,204 square miles. Just how much of the swamp area contains peat is unknown, but it is certainly a considerable proportion, as the conditions are usually favorable to the accumulation of peat.

The occurrence of peat in New York has been described very fully in the early reports of Beck, Mather and Hall and more recently in the papers by Ries and Parsons, to which references will be found at the end of this article. Parsons summarizes the general distribution of peat in the State in the following manner: "It would be difficult to find a spot in the entire State that is more than 10 miles from a swamp, and though not all swamps furnish peat, yet it is within the limits of probability that peat will be found in at least half of them. The most extensive group of swamps is found in the Finger Lakes region and the lowlands near the St Lawrence river, though the largest swamp of all, the Drowned Lands of the Walkill, is in the mountainous part of Orange county, which borders New Jersey. Many peat deposits are found in the Adirondacks, and,

as exploration is carried farther, the recorded number will be much greater. The depth of the Adirondack swamps is likely to be much greater than most of the swamps in the central and western portions of the State, though the few visited by the writer are not very deep."

Details of occurrence. Mather¹ estimated that 1000 acres of peat land were to be found in New York, Westchester and Putnam counties, with a probable yield of 2,000,000 cords. Much of the area, no doubt, has long since been converted to such use that the peat is no longer recoverable. This applies to New York and Westchester counties particularly, but wild swamp lands are still to be found in Putnam county.

Orange county once contained 40,000 acres of peat swamps (Ries). The largest single area is that of the Drowned Lands, west of Warwick, which once covered 17,000 acres. A good part has been drained and converted to agricultural use, but there are still areas of open and forest-covered peat lands. Parsons found the peat to vary from almost nothing to 18 feet in thickness. Measured sections are reported by him as follows: Pine island, 18 feet, bottom not reached; Black Walnut island, 18 feet, bottom not reached; one-half of a mile west of Durandville, 16 feet; 1½ miles west of Durandville, 17 feet; one-half of a mile west of Big island, 12½ feet, bottom not reached; 1 mile west of Big island, 12½ feet, bottom not reached; Florida, 18 feet, bottom not reached.

The Greycourt meadows, between Chester and Greycourt along the Erie Railroad, contain about 3000 acres of peat land now employed in agriculture.

Near Pine Plains, Dutchess county, peat is found on the margin of Stissing pond and south of there along the valley. Mather estimated 500 acres of a 6-foot bed in this vicinity, but Parsons's tests indicated the peat to be patchy.

In northern New York occur numerous ponds, lakes and swamps which contain more or less peat. An extensive tract of peat is found on the line of the Champlain canal in Kingsbury township, Washington county. Also in the vicinity of Fort Edward and Glens Falls in the Hudson valley are peat lands in areas of a few acres to several hundred acres extent. Plants for utilizing the peat were erected near Glens Falls some 40 years ago. One of these plants operated in the Rosecrans swamp northeast of that city. A second plant was built for working the peat between Glens Falls and French mountain on the Lake George road. In neither case was any large output made.

¹Geology of First District of New York. Third Ann. Rep't, p. 74.

Probably the largest areas of peat in northern New York are on the northwestern side of the Adirondacks, where the slope of the land is much more gradual than elsewhere and the drainage has been obstructed by glacial accumulations. Nearly all the streams that flow out of the Adirondacks on that side are colored by organic matter derived from swamps on their headwaters. The Black, Oswegatchie, Indian and Grass rivers all drain extensive swamp lands, but very little is known as to the character and quantity of peat found in them. A dredge for recovering the peat on the bottom of Black lake, which is an expanded part of Oswegatchie river, was built a few years since at Heuvelton, near Ogdensburg, but was never placed in operation. The engineers in charge of the enterprise reported that a large supply of peat occurs on the borders of the lake.

In central and western New York occur some of the largest marshes in the whole State. Just west of Rome and northwest of that city on the line of the Rome, Watertown and Ogdensburg Railroad there are several thousand acres of bog lands which recently have been partially drained and put under cultivation. The new barge canal was instrumental in effecting the improvement of this tract, as it supplied an outlet for the water several feet below the old channel of the Erie. The peat and muck beds range up to 40 feet thick. A section given by Ries shows: Swamp muck, 3 to 5 feet; peat, 3 to 6 feet; moss peat, 8 to 12 inches; shell marl, 2 to 4 inches; mud, 1 to 2 feet; gravel, 1 to 3 feet; hard pan, 18 to 20 feet. A factory for converting the peat into commercial fuel was erected near Rome some years ago, but was not long in operation.

The Cowaselon and Cicero swamps lie just south of Oneida lake and extend for nearly 25 miles in an east-west direction with an extreme width of 2 miles. Cowaselon swamp is the eastern part, north and northwest of Canastota, and has been mostly drained by the Douglas ditch, providing excellent land for onion-growing. From $3\frac{1}{2}$ to 6 feet of peat are shown in the sections by Parsons between Ontiontown and Ognon.

Montezuma marshes comprise a tract north of Cayuga lake, some 8 miles long and 2 or 3 miles wide. There is a bed of peat over much of the area, with a thick deposit of marl below. The marshes are intersected by the Seneca and Clyde rivers which periodically flood the lands and deposit more or less silt, so that the peat is not of first quality.

Oak Orchard swamp is an extensive area of partly forest covered land in Genesee and Orleans counties. It includes a large proportion

of excellent agricultural land. The eastern section of the swamp is reported by Parsons to have the greater thickness of peat, but apparently little of it would be available for working in view of the value of the soil for other purposes.

Uses of peat. A great deal of experimentation has been carried on with a view to the industrial utilization of the peat beds of the State. Plants have been erected at one time or another in the principal bogs, but apparently attained little commercial success as in most instances operations were discontinued after brief trials. Among the causes leading to failures, no doubt, one of the most common has been the lack of experience on the part of the designers of plants in regard to the methods of preparation and handling peat as worked out in other countries which have an established industry. Much wasted effort has been directed to the designing of new types of machinery for harvesting, briquetting and drying the peat which a little inquiry into the matter would have proved futile at the outset.

Peat in its natural condition is not a fuel. As it comes from the bed it carries 90 per cent, and often more, of water. That is 100 pounds of the wet peat will yield only 10 pounds of water-free material. It is a difficult and expensive operation to expel all of the water and to do so mechanically with artificial heat is impracticable, as it entails a consumption of heat units in the drying apparatus that is commensurate with, or in excess of, the heating value of the dried peat that is recovered. Consequently the drying must be carried out for the most part at least by natural means, that is by air-drying, the method employed in the peat bogs of Ireland and Sweden for converting the peat into domestic fuel. By air-drying the moisture content may be reduced to 25 or 30 per cent. The remaining water seems to be held in chemical combination with the cellulose and its expulsion is accomplished only at temperatures above the normal. When peat is heated at high temperature in a retort to drive off the moisture there is a loss of combustible matter in the peat itself.

This problem of the drying of peat has been the principal stumbling block in the road of commercial enterprises. Mechanical drying, so far, has proved a failure, and the only practicable method seems to be that of air drying which means of course an intermittent operation confined to a few months of the year. Peat that has been air-dried, containing around 25 to 30 per cent water, has about one-half the heating value of good commercial coal.

Perhaps the most promising field for the employment of peat as fuel is in connection with the gas-producer for power plants whereby the recovery of the nitrogen content in the form of ammonium sulphate becomes practicable. In this case it is not necessary to carry the drying operation beyond a point readily attained by natural means; a further advantage inherent in this method is that the peat requires no compressing as is necessary when it is to be employed at a distance from the bog. The nitrogen content of the peat then becomes a matter of importance, since with proper apparatus for its recovery a very considerable drawback upon the operating costs might be realized. The gas produced by the combustion of the peat, after removal of the nitrogen compounds, is used for fuel or power.

Undoubtedly the most thorough investigation of the possibilities of peat as fuel that has been carried out in recent years is that of the Department of Mines of Canada which conducted working tests over a period of two years under expert guidance. A report¹ prepared by B. F. Haanel gives a full account of the results obtained, as well as a review of the progress made in the use of peat abroad. The following paragraph from this report is presented as a succinct and reliable statement of the situation in regard to the commercial aspects of peat for fuel:

"Unless the manufacture of peat fuel is conducted on a bog situated reasonably near a community which is able to take over the entire output produced, peat manufactured for domestic or fuel purposes alone would not prove a profitable venture. This is due to the comparatively low heating value of peat, to its moisture content and to the large volumes it occupies per heat unit, as compared with coal; and when to these disadvantages is added that of high freight rates per ton, the reason of the foregoing statement will be obvious. But while peat may serve as a domestic fuel in only certain cases, it may be well adapted for the production of power, or as fuel gas. This is especially so in the case of peat which has a high nitrogen content, since this element can be profitably recovered in the ammonia gas formed in the by-product recovery producer. According to the process employed in by-product recovery work, the ammonia gas is fixed with sulphuric acid, and the resulting product "ammonium sulphate" is then sold for agricultural purposes. The demand for this product is, today, greater than the supply, consequently its price per unit is somewhat high. Whenever, therefore, the nitrogen content of the peat is sufficiently high, the

¹ Peat, Lignite and Coal. Mines Branch, Department of Mines, Ottawa, 1914

production of a fuel, or power gas, accompanied by by-product recovery, would prove profitable. But in the case of the production of power, the same economics must be introduced into the manufacture of power that apply to a domestic fuel, and even though the content of nitrogen is well above the average, any increase in the cost of fuel rapidly decreases the expected profits. Peat is a low grade fuel which must be manufactured and sold at a comparatively low cost, if it is desired that it should serve as a substitute for coal. It is evident, therefore, for the foregoing reasons, that the manufacture of peat fuel does not hold forth any glowing prospects for getting rich quickly, although reasonable and very good profits should in almost every case be realized when the industry is run on a business-like basis. But the element of speculation, and some of the commonly practiced methods of promotion must be eradicated if the peat industry is ever to become an accomplished fact."

The largest development in the use of peat in this country has been in the agricultural field, wherein the material is used both directly on soils and in mixture with chemical fertilizers. The more thoroughly decomposed nitrogenous peats are preferred for this purpose. A special form that has excited some interest in agricultural experiments is bacterized peat, prepared by sterilizing the natural peat at a temperature of 130° C. approximately and then adding lime until the material is neutral. After this the peat is inoculated with bacteria which have the property of fixing atmospheric nitrogen. Bacterized peat is supposed to enrich as well as stimulate the soil. Reports by agricultural experts do not agree as to the results obtained in the use of this preparation.

It has long been a common practice in many parts of the State to employ the black, decomposed peat or muck as an amendment for soils. More of this material has been employed than for all other purposes. Its use is recommended in soils deficient in humus; it also improves the physical condition of certain soils, helping sandy soils to retain moisture and making clayey soils more open and porous. No accurate information in regard to the quantity of material employed in this way has been secured.

References

- Beck, Lewis C. Mineralogy of New York, 1842
Hall, James. Geology of New York. Report on the Fourth District, 1843
Mather, W. W. Geology of New York. Report on the First District, 1843
Parsons, Arthur L. Peat, Its Formation, Uses and Occurrence in New York. N. Y. State Geol. 23d Rep't, 1904
Ries, H. Uses of Peat and its Occurrence in New York. N. Y. State Geol. 21st Ann. Rep't, 1903

PETROLEUM

The oil region of the State is in the southwestern part and comprises a stretch along the Pennsylvania border in Cattaraugus, Allegany and Steuben counties. The area altogether is about 40 miles long east and west and extends 15 miles or so north from the state line. It is the northerly extension of the Appalachian field, which reaches its main development in Pennsylvania, Ohio and West Virginia. There are a number of pools within the area and their bounds have now been accurately delimited by exploration. No new pools of importance have been discovered within the last 20 years.

The first oil well in the New York field was drilled at Limestone, Cattaraugus county, in 1864. The boring showed oil but not in paying quantities. It attracted notice to the locality, however, and a deeper well soon after encountered a heavy flow that aroused interest in the possibilities of the section. Active work in Cattaraugus county did not begin until several years later, in fact the first systematic exploration dates from 1875-6 with the spread of the prospectors from the Pennsylvania region which at about that time was the scene of a tremendous oil boom. By 1878 there were over 250 wells in Carrollton township and oil had been found in the adjoining Allegany township. The exploration of the Allegany county area began in 1881 with the discovery of the Richburg pool, one of the largest in the State.

Production. Statistics of production are available only for the period from 1891 on, as in earlier years the output was combined with that of Pennsylvania. The following figures have been compiled from the volumes of the *Mineral Resources* and from reports received directly from the field.

Production of petroleum in New York

YEAR	BARRELS	VALUE
1891.....	1 585 030	\$1 061 970
1892.....	1 273 343	708 297
1893.....	1 031 391	660 000
1894.....	942 431	790 464
1895.....	912 948	1 240 468
1896.....	1 205 220	1 420 653
1897.....	1 279 155	1 005 736
1898.....	1 205 250	1 098 284
1899.....	1 320 909	1 708 926
1900.....	1 300 925	1 759 501

Production of petrolum in New York (*concluded*)

YEAR	BARRELS	VALUE
1901.....	1 206 618	\$1 460 008
1902.....	1 119 730	1 530 852
1903.....	1 162 978	1 849 135
1904.....	1 036 179	1 709 770
1905.....	949 511	1 566 931
1906.....	1 043 088	1 721 095
1907.....	1 052 324	1 736 335
1908.....	1 160 128	2 071 533
1909.....	1 160 402	1 914 663
1910.....	1 073 650	1 458 194
1911.....	955 314	1 251 461
1912.....	782 661	1 338 350
1913.....	916 873	2 255 508
1914.....	933 511	1 773 671
1915.....	928 540	1 476 378
1916.....	874 087	2 190 195
1917.....	879 685	2 850 378
1918.....	808 843	3 307 814

The crest of production had already been passed by 1891. The largest output was made in the years 1880-1885 when the flow reached as high as 5,000,000 barrels annually. The number of producing wells at present is in excess of 11,000. According to the *Mineral Resources* for 1916, there were 11,200 wells in production on December 31st of that year. About 3000 of the total are in Cattaraugus county, 8000 in Allegany county and the remainder in Steuben county.

It will be seen from the above table that the production during the last four years has varied very little, averaging a little under 1,000,000 barrels annually. The maintenance of the output at such an even rate during the declining stages of the industry is quite remarkable and in striking contrast with the history of most fields. This is largely the result of adherence to a policy of conservation and economy on the part of the producers. The product of the New York wells is too valuable to be wasted, commanding the highest market prices paid for Appalachian oils. The economy with which operations are conducted is indicated by the fact that the average well yield is only about one-fourth of a barrel a day. The development of the remaining areas of undrilled ground and the redrilling of intermediate wells may be expected to report an active industry for a number of years to come. The product is handled by several pipe-line companies and shippers, including the

following: Columbia Pipe Line Co., Union Pipe Line Co., Fords Brook Pipe Line Co., Buena Vista Oil Co., and Madison Pipe Line Co. of Wellsville; Vacuum Oil Co., Rochester; New York Transit Co., Olean; Emery Pipe Line, Allegany Pipe Line Co., Tide Water Pipe Co., Limited, and Kendall Refining Co., of Bradford, Pa. There are refineries at Wellsville and Olean.

Geological occurrence. The oil is found in fine-grained, dark-colored sandstones which have been assigned generally to the Chemung formation of the Upper Devonian. The Chemung in this section is partly mantled by conglomerates and sandstones of the Carboniferous, the only representative of the coal-bearing series to occur in the State. The precise horizons of the oil can not be definitely stated and their determination will require very detailed field work which hitherto has not been practicable on account of the lack of accurate field maps.

The main oil sand in Cattaraugus county is called "Bradford" from the Bradford, Pa., district, which is just across the state line. In Allegany county the main horizon is recognized as the "Richburg." In the southeastern part of that county and extending over into Steuben county is the Andover field with two producing sands, the upper called the "Penney" and the lower called the "Fulmer Valley" sand. In the Bolivar or Richburg pool in the southwestern section the main "Richburg" sand is succeeded 80 feet below by the "Waugh and Porter" sand. In the small Scio field which lies about midway of the county and north of the others there are two sands 280 feet apart, the uppermost being called the "Richburg" and the lower the "Waugh and Porter."

The depth to the sands varies from 800 feet in the valley wells to 2000 feet or more in the borings made on the high ground. The following details of the different pools are taken mainly from the articles by I. P. Bishop¹ and D. A. Van Ingen² in the reports of the New York State Museum.

Allegany county pools. The Andover pool lies mainly in the town of Andover, but extends over the line into the town of Greenwood, Steuben county. The original wells were drilled for gas and the first ones were put down in 1889. Their depth ranges from 700 to 1300 feet, depending on the surface configuration. There is a considerable flow of gas, more than sufficient to supply power for pumping. Some sample well records are here given.

¹ N. Y. State Mus. Ann. Rep't 51, v. 2, 1897 and 53, v. 1, 1899.

² N. Y. State Mus. Bul. 15, 1895.

Richards well, lot 20, Greenwood, Steuben county.

Drive pipe.....	60 feet
Casing.....	260
Gas sand (24 feet) at.....	746
Gray sand and shale to.....	777.5
Bottom.....	814

Urdike well, near county line.

Drive pipe.....	40 feet
Casing.....	330
Oil sand with gas at.....	627
Bottom of sand at.....	654
Bottom.....	688

The southwestern extension of the Andover pool is designated sometimes as the Fulmer Valley pool.

The Alma pool lies close to the state line about midway between the eastern and western limits of the townships. The wells are from 800 to 1500 feet deep. The pool lies along a northeast-southwest axis within sandstone 10 to 20 feet thick. A condensed record of one of the wells follows:

Surface materials.....	100 feet
Sandstone and shale.....	210
Sandstone with water.....	218
Sandstone and shale.....	975
Sandstone with oil and water.....	995
Shale.....	I 109
Top of oil sand.....	I 126
Harder gray sandstone.....	I 143
Bottom of oil sand.....	I 153
Gray shale.....	I 177

The Waugh and Porter pool covers a small area to the west of the Alma pool, in the town of Bolivar. It was opened in 1882. The wells tap the "Richburg" and "Waugh and Porter" sands which are separated by shale. The wells have a depth of from 1350 to 1700 feet.

The Bolivar, Richburg and Wirt pools form a contiguous and coalescent group, the oldest and largest section of the Allegany county district. They underlie parts of Alma, Scio, Bolivar, Wirt, Genesee and Clarksville townships. The earliest wells were put down in 1882, at Richburg about in the center of the district. The "Richburg" sand is here from 25 to 50 feet thick and lies 1400 to 1800 feet deep. A sample record of a well near Richburg follows.

Well No. 2, lot 33, Bolivar.

Gas sand (20 feet) at.....	I 341 feet
Oil sand at.....	I 383.5
Bottom oil sand at.....	I 408.5
Bottom of well.....	I 419

The Clarksville and Niles pools lie to the west and north of the preceding and occupy a narrow belt with a northeast-southwest axis. The Clarksville is the larger, extending about five miles in the towns of Clarksville and Wirt. The Niles is just to the northeast in the town of Wirt, and about a mile long. The two are separated by a dry belt of one-half of a mile. Most of the wells are from 1000 to 1500 feet deep.

Nile well.

Blue shale.....	400 feet
White sand (first sand?) at.....	630
Soft blue rock at.....	880
Second sand (dark).....	900
Blue shale.....	910
Slate with oil sand (3-8 feet).....	1 200
Dark shale.....	1 600

The Scio pool near the village of Scio, is a small pool lying in an isolated portion and apparently independent of the others. The sand is shallow, 450 to 900 feet from the surface, and the oil of light gravity. There is a very little gas in this pool.

In northern Allegany county is the Short Tract or Granger pool, in the town of Granger near the Livingston county line. It was the scene of active exploration in 1906-8 when about thirty wells were put down which, however, did not prove profitable. The pool has since been abandoned. Oil was reported in a well drilled near Swain in the town of Grove at a depth of 740 feet. The deep well at Canaseraga in the town of Burns, mentioned under the head of natural gas, found a little oil at 275 feet in gray sand and again at 875 feet in chocolate sand.

Cattaraugus county. The oil district includes a small area in the southern townships mainly in Olean, Allegany, Carrollton and Red House. A few successful wells have been opened also in the town of Humphrey in the second tier above the Pennsylvania line. As in Allegany county there are a number of individual pools whose boundaries have now been well defined by exploration. The largest of these lies directly on the boundary and is an immediate extension of the Bradford district so that it may be designated as such. The pool is about 10 miles long east and west and $2\frac{1}{2}$ miles wide as a maximum, with a total area of about 15 square miles. The easternmost part in the town of Olean is sometimes referred to as the Haymaker pool, as it is set off from the rest by a narrow strip of dry ground. The Allegany pool is farther north in the town of Allegany and west of Olean. It is intersected by the Allegany river

and measures about 4 miles long to 2 miles wide. The Chipmunk and Flatstone are connected pools, mainly in the town of Carrollton but extending over into the town of Allegany. The Rice Brook, a small pool, lies to the west of this near the west border of Carrollton township. There are three or four little pools with a few wells each in the town of Red House; also one in the town of Humphrey about 5 miles north of the Allegany pool. A number of well records for the Cattaraugus county district are given in Bishop's paper¹ from which a few examples are here reproduced.

Bunnell well no. 2, lot 3, Allegany.

To rock.....	25 feet
Casing.....	285
Salt water at.....	400
First sand (gas).....	510
Second sand.....	800
Gas at.....	I 020
Top third sand.....	I 080
Bottom third sand.....	I 157
Bottom of well.....	I 197

Well no. 1, section 6, Olean.

Casing.....	244 feet
Top Chipmunk sand at.....	850
Bottom Chipmunk sand at.....	880
Top second sand at.....	990
Bottom second sand at.....	I 051
Top third sand (shells) at.....	I 390
Bottom third sand (shells) at.....	I 451
Bottom of well.....	I 714

Well on John King farm, Carrollton.

Casing.....	270 feet
Gas at.....	570
Top oil sand (24 feet).....	575
Bottom oil sand at.....	599

Well no. 1, Rumsey farm, Carrollton.

Drift.....	240 feet
Cement gravel at.....	284
Drive pipe.....	285
Oil and salt water.....	480
A little oil at.....	580
Flow of gas and oil at.....	800
Bottom of well.....	882

Well on Loup farm, Olean. The record of this well is compiled from data given by C. A. Ashburner (see references below), who reports it to have been the largest gas producer in the region that had been opened up to the year 1877. The yield was estimated

¹ N. Y. State Mus. Ann. Rep't 51, v. 2.

by him at 24,480,000 cubic feet of gas and about one barrel of oil a day. The top of the oil sand is put at 1785 feet below the bottom of the Olean conglomerate and the well is stated by Ashburner to lie in a syncline.

To rock.....	16 feet
Casing.....	196
Gray shales and slate.....	625
Fine shelly sandstone.....	675
Shales.....	870
Fine sandstone and shales alternating.....	960
First gas sand.....	1180
Main (Bradford) sand.....	1230

Well on Joseph Renaldi farm, lot 45, Red House.

Casing.....	300 feet
Sand (Chipmunk?) at.....	680
Top second sand at.....	1049
Bottom second sand at.....	1059
Brown sand at.....	1095
Top Bradford sand at.....	1359
Bottom Bradford sand at.....	1429
Bottom of well.....	1562

References

- Ashburner, C. A. Petroleum and Natural Gas in New York State. Amer. Inst. Min. Eng. Trans. vol. 16, 1888
- Bishop, I. P. Petroleum and Natural Gas in Western New York. N. Y. State Mus. Ann. Rep't 51, v. 2, 1899
- . Oil and Gas in Southwestern New York. N. Y. State Mus. Ann. Rep't 53, v. 1, 1901
- Orton, Edward. Petroleum and Natural Gas in New York. N. Y. State Mus. Bul. 30, 1899

PYRITE

There has been no marked increase in the production of pyrite for acid making in the last few years, but developments are now in progress that will doubtless lead to a considerable gain in productive capacity in the near future. These developments have centered about the St Lawrence and Jefferson county district, on the north-west side of the Adirondacks, where mining operations on a fairly extensive basis have been carried on for the last fifteen or twenty years. This district contains great resources of easily available ores, but the deposits are low grade and their commercial exploitation involves a considerable capital outlay for mining and milling equipment necessary to place an undertaking on a successful working basis.

Information as to the general distribution and features of the pyrite deposits in Jefferson and St Lawrence counties has recently appeared in a report¹ by A. F. Buddington, prepared under the direction of the State Geological Survey during the summer of 1917. A brief description of the principal ore deposits of the district were contributed by the writer to the Engineering and Mining Journal (December 1, 1917).

Nature of the deposits. The pyrite deposits are usually spoken of as veins, but they are really bands or zones of the country gneisses and schists impregnated with the sulphide and more or less vitreous quartz. The mineral occurs in two forms: as finely divided particles more or less evenly distributed through the gangue and as aggregates of coarser grains and crystals in bunches, veinlets and stringers of more irregular distribution. Some of the ore contains little else than fine granular pyrite in a gangue consisting of feldspar, quartz and mica, with usually considerable amounts of chloritic material of secondary origin. In other examples the ore is a network of small stringers or veinlets intersecting the gneiss or is made up of alternating bands of sulphides and country rock, in both of which types the pyrite is much coarser than in the disseminated ores. As a rule the grade of the ore depends upon the extent to which the veining and banding occurs. The disseminated variety unmarked by these features rarely contains more than ten or fifteen per cent of sulphur. The richer grades, in which there is a considerable percentage of coarse pyrite, average 25 to 30 per cent sulphur.

Some pyrrhotite is usually present along with the pyrite. It is rarely intermixed with the latter, but tends to segregate in a separate part of the deposit, for example, along the walls or in independent bodies. It is much less common than the other sulphide and rarely is found in any considerable bodies. In sulphur content the pyrrhotite ores are practically on a par with the pyrite ores, notwithstanding the wide difference in composition of the two minerals.

The pyrite deposits show marked persistence along their strike, and where they have been mined underground they have been found to be persistent on the dip as well. The thickness, however, is usually small compared with other dimensions. In most localities they are not more than 15 to 20 feet thick, measured from wall to wall. A maximum thickness of 40 feet is found in parts of the Anna mine, near Hermon, and 80 feet is reported to have been found in one of the deposits at Pyrites. In the long stretch in which the deposits

¹ N. Y. State Defense Council Bul. 1, Albany, 1917.

outcrop between Antwerp and Keene the thickness averages in most places between 10 and 12 feet.

Distribution. The report by Buddington, already referred to, describes the pyrite deposits as occupying long belts of which seven in all are noted in St Lawrence and Jefferson counties. The more important of the belts form a single major belt or zone some 40 miles long and from 3 to 4 miles wide extending in a northeast-southwest direction from near Antwerp, Jefferson county, to near Canton, St Lawrence county. This zone is practically conterminous with the great belt of Grenville strata in that region. In fact, the gneisses and schists in which the ores are usually found are part of the Grenville series of metamorphosed sediments which include also crystalline limestone as an important member. Buddington defines the principal belts as follows: Pyrites-Hermon belt on the northeast end. A narrow belt of Grenville gneiss in the towns of De Kalb and Gouverneur, running northeast from the Cole mine. A belt of gneiss occurring in the towns of Pierrepont, Hermon, Fowler, Rossie, Antwerp and Philadelphia. The Laidlaw belt extending from Oxbow into the town of Antwerp, between Halls Corners and Oxbow. Another belt lies two-thirds of a mile southwest of Oxbow. In addition there are smaller areas of pyritic gneisses in the vicinity of Silvia lake, town of Fowler, and just east of Talleville, town of Edwards. The principal mining operations hitherto have been centered on the deposits at Pyrites, the Stella Mines near Hermon and the Cole property in the vicinity of Gouverneur. The most promising of the undeveloped deposits probably, all things considered, are those situated in the Keene-Antwerp belt in the vicinity of Oxbow.

Mines at Pyrites. A vein or band of pyrite ore is exposed along the Grass river in the vicinity of Pyrites for a distance of over one-half of a mile. The vein as shown on the surface ranges from 8 to 20 feet thick and has been attacked in several places by open-cut excavations. It also has been worked under ground. The principal mine operations were in the period 1886-1906, when the High Falls Pyrites Company and later the National Pyrites Company exploited the deposit. Two inclined shafts were put down along the dip of the ore. A mill of 50 tons daily capacity was erected at the mine for concentration. In 1907 the mines were taken over by the Oliver Mining Company, which carried out extensive exploratory operations with the diamond drill. These are reported to have been successful in showing the presence of large resources of the ore, but no active mining has since been undertaken.

About 900 tons of ore were taken out by the company for experiment, which are reported to have averaged 22 per cent sulphur and to have yielded 300 tons of concentrates. In the earlier period of active mining the deposits had been worked to a maximum depth of 250 feet. The better grade of ore is said to occur in shoots which have a northeasterly trend and a northwest dip. Pyrrhotite occurs in considerable bodies, but is not mixed with the pyrite to any extent.

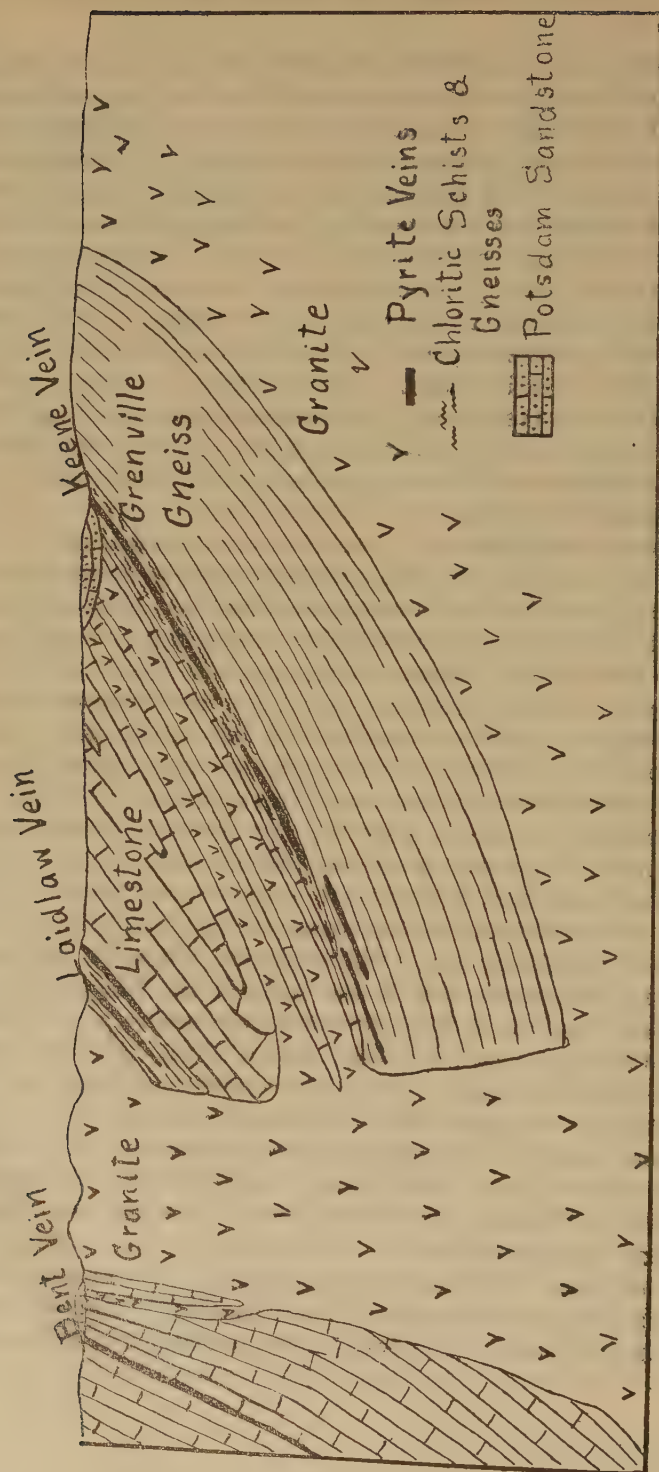
Stella mines. These are 1 mile north of Hermon. They include workings on the Stella vein which were first opened and has been exploited to a depth of 900 feet on the dip and for 1100 feet along the strike, with an average thickness of from 10 to 12 feet and the Anna workings which are based on parallel ore bands which measure 50 feet thick in the aggregate and are tapped by a single shaft. The mines are now operated by the St Lawrence Pyrites Company who took over the property about 1905.

The upper vein on which the Stella shaft is situated is a thin band which shows great regularity and persistence. It has a northeasterly strike and a dip to the northwest of from 20 to 30 degrees. Work on the deposit has been discontinued of late years and operations carried on solely in the Anna mine, where there are four parallel ore bands with an aggregate thickness of 50 feet or more. The individual veins are separated from each other by 75 to 100 feet of country rock which here is a basic hornblende type that may be a metamorphosed gabbro. The Anna shaft is over 600 feet deep and the connected levels extend 1800 feet along the strike. The crude ore is treated in a mill equipped with jigs and tables. The concentrates as shipped carry about 45 per cent sulphur. The milling capacity is about 250 tons crude ore a day with one-third to one-half of that amount in concentrates.

Cole mine. This property was worked for several years by the Hinckley Fibre Company who shipped the ore crude for use in sulphide manufacture. In 1917 the New York Pyrites Company was organized for its operation. The new undertaking has begun shipments of crude ore, but contemplates the erection of a mill which will enable the output to be marketed in a more desirable form for acid manufacture. The installation of mine and milling plan has been in progress during 1918. The shape of the ore bodies at this locality shows a considerable departure from the simple form that characterizes most of the other deposits in the district. The structure of the deposit, however, has not yet been satisfactorily worked out. In the early operations two bands or veins were

encountered, on one of which the shaft was sunk 225 feet in 15 to 18 feet of ore with a northwest strike. On the hanging side, separated by 15 feet of schist, is a second body which was drifted on for 90 feet in a northeast direction and for 60 feet at right angles thereto. It was developed by later operations that the vein in which the shaft is located and the overlying ore body are connected on the northwest side by a band of ore 10 feet thick. It seems likely that the ore in this locality has been folded subsequent to its deposition. Recently a series of prospect pits has been made to the southeast of the mine between there and the highway. A thickness of 30 feet of ore is here indicated. The pyrite is of a different type than seen in most of the mines. It is conspicuously banded in alternate layers of coarse and fine material. Some specimens are practically pure sulphides and the average content of the run of mine is well over 25 per cent sulphur.

Keene-Antwerp deposits. One of the most persistent belts in the region is along the line of the railroad between Keene station and Antwerp, paralleling the railroad on the west and lying along a well-defined valley which is defined by low granite ridges on the east side with a more general sloping ridge opposite, usually of limestone. The belt is about 5 miles long and is composed of successive bands of pyrite schist which occur at slightly variant horizons. The rich portions of the schist that occur here and there afford promising ground for prospecting if not actually for mine developments. Some of these richer occurrences are on the Caledonia, Keene, Morgan, Wright and Dickinson properties, all of which contain hematite ores that have been worked on a larger or smaller scale in years past. On the northern end the pyrite occurs mostly in finely divided condition distributed in a schist composed of quartz, feldspar and chlorite which forms one of the walls of the hematite deposits. Samples of the ores of this type show on analysis 20 per cent sulphur or a little more. In the middle section of the belt there is more of the coarse secondary pyrite which occurs in veinlets and bands that intersect the schist. Such material is not only higher in grade but there is more suitable material for concentration. The individual bodies measure from 15 to 20 feet wide as shown on the surface and can be followed for several hundred feet in places without apparent diminution in size. Up to the year 1918 practically no work had been done on these deposits and their extent seems to have escaped the attention of those engaged in mining in other parts of the district. The development operations have been under



Diagrammatic structure section to show interrelations of rocks and Pyrite Veins (after Buddington)

way during the spring and summer of the current year and some shipments of lump ore have been made.

Deposits near Oxbow. Pyrite ore outcrops in force on the Laidlaw farm 1 mile southeast of Oxbow and just south of Antwerp highway. The exposures lie on the west face of a small knob which is composed of garnet-biotite gneiss with about 50 feet of pyritic gneiss exposed on the northwest side. The outcrop of the ore is marked by a heavy iron-stained cap. The richer ore occurs near the top of the exposed band of pyritic gneiss along the eastern flank of the hill. It has been prospected in two or three places and near the southern end of the hill a shallow shaft has been sunk. Another prospect lies near the north end. Little can be seen in these openings but about 150 feet south of the shaft ore appears in outcrop for a distance of 50 feet along the strike with a width of about 22 feet. The upper 18 feet of this band is fairly rich pyrite ore. The lower four feet consists of pyrrhotite. Samples of the vein taken in the shaft opening showed on analysis 28 to 29 per cent sulphur.

Pyrite schists occur on the Frank Bent farm $2\frac{1}{2}$ miles southwest of Oxbow where the band of schists or gneiss has a thickness altogether of 50 to 60 feet. The richer ore occurs in the central part of the band with about 25 feet that is rather heavily charged with sulphides. In one place a prospect has been put down for a few feet in the ore. The total length of the exposed vein is about 400 feet but there is no doubt it extends much farther than that. The pyrite outcrops a short distance from some iron ore pits. A sample of the sulphides made up of several specimens taken from different parts of the vein returned 22.15 per cent sulphur.

Other pyrite showings in St Lawrence county. In the report by Buddington previously noted, mention is made of a test drilling by the St Lawrence Pyrite Company at a locality one-quarter of a mile west of Pyrites. The drill is said to have encountered 11 feet of fairly rich ore, beginning at 94 feet from the surface. A prospect pit is found 1 mile from Pyrites in a direction a little south of west. The pit is shallow and reveals an ore made up of pyrite and pyrrhotite in about equal quantities. The two minerals occur in irregular branching veinlets with occasional pockets and bunches of the sulphides.

In the vicinity of the Ore-Bed school, town of Hermon, are found ore bands of pyritic gneiss which have been prospected to a small extent. One band of the gneiss forms the hill on the east side of the road one-quarter of a mile north of the school house and consists of an injected gneiss of which the outcrop is marked by the usual

rusty appearance. Two veins of pyrite occur but they are poorly exposed and their size is undeterminable from present observations.

A prospect shaft was put down some years ago on the Alexander Parr farm, now owned by Henry Fleming, situated 3 miles northeast of Bigelow, in the town of De Kalb. The portion of the vein to be seen in the shaft, which is partially filled with water, consists of about $6\frac{1}{2}$ feet of pyrrhotite. About 50 yards north of the shaft a prospect exposes about 9 feet of pyrrhotite. Typical specimens of the ore returned 20.80 per cent sulphur and 0.22 per cent arsenic.

The Mitchell prospect is in the town of De Kalb, about $2\frac{2}{3}$ miles northeast of Bigelow, on property now owned by D. G. Styles, but which formerly belonged to Calvin Mitchell. The opening, a shaft of uncertain depth, is on the southeast edge of a small ridge just north of Indian creek. The shaft is said to have been excavated in the spring of 1904. It is now filled with water to within about 20 feet of the top, and in the exposed part shows 7 to 8 feet of pyrite ore, in the middle of which is a band of pyrrhotite gneiss. About 35 feet northeast of the shaft a small prospect exposed 7 feet of sulphides. At a distance of 200 feet southwest of the shaft another prospect reveals about 2 feet of pyrrhotite ore. An analysis of the pyrrhotite showed 23.48 per cent sulphur and 0.16 per cent arsenic. It is probable that the whole vein will average about 25 per cent of sulphur.

The Styles shaft is about $1\frac{1}{5}$ miles northeast of Bigelow, near the elbow of Indian creek, on land owned by D. G. Styles. It was put down in 1904 at the same time as the Mitchell shaft. About 9 feet of pyritic gneiss is exposed in the shaft, the vein being composed of alternate bands of sulphides and lean rock. The ore consequently varies in character from place to place and the average is probably about 20 per cent sulphur.

The prospect known as the Henricks shaft is located in the town of De Kalb, $1\frac{1}{2}$ miles southwest of Bigelow and southwest of the railroad which crosses Boland creek. The shaft is now flooded, but apparently the vein is narrow, averaging about two feet thick. The sulphur content is reported to be about 30 per cent. The same vein has been traced by trenching and by pits for a distance of 300 feet, and at the southern end close to the railroad tracks it widens to 6 feet. Limestone forms the foot wall of the gneiss.

Pyrite in graphite ores. Pyrite occurs in association with the graphite ores which are mainly exposed on the eastern side of the Adirondacks in Essex, Warren and Washington counties. In most of the deposits the content is small and the pyrite is present in finely

divided particles difficult to separate from the gangue. In some places, however, it forms a considerable percentage of the total mass, and in such form that it could be readily recovered as a byproduct in the process of separation of the graphite. At one of the mines pyrite concentrates of commercial grade are now produced.

Pyrrhotite in southeastern New York. A body of pyrrhotite of some size occurs on Anthony's Nose, the bold prominence that arises on the east shore of the Hudson river just north of Peekskill. Mine operations were carried on at the locality for several years succeeding 1865, the output being used for sulphuric acid manufacture in works situated nearby on the river front. The ore is said to have carried about 28 per cent sulphur in the average and to have been free from arsenic. The deposit was mined to a depth of from 300 to 400 feet; and its thickness in the workings ranged from 20 to 30 feet and the width on the line of strike 50 feet. The immediate walls consist of a light-colored gneiss composed of quartz, plagioclase and a little hornblende, but a basic gneiss that may represent an altered gabbro outcrops within a short distance.

Pyrite in shales. An occurrence of pyrite in bedded shales that was recently brought to the writer's notice deserves some mention in this place on account of the unusual conditions it illustrates, although belonging to a type that is not at all uncommon. The association of pyrite with clay sediments is so frequent as to be hardly noteworthy. In the present instance, however, the pyrite is more than ordinarily abundant and forms nodules and aggregates of such size that it can be readily freed from the enclosing rock, and when so separated is of commercial grade. The deposit consists of about 25 feet of beds comprising the Brayman shales, as exposed in the vicinity of Schoharie village, on the west side of Schoharie creek. The locality, where the pyrite occurs in considerable abundance, is on the Gebhard farm, now owned by R. Veenfliet jr, just outside of the village. For some hundreds of feet the shale occurs in a vertical bank topped by hard thick beds of Cobleskill dolomite, the two formations inclining at a low angle to the south and gradually disappearing from view under cover of the higher strata as they are followed in that direction. Throughout the 15 feet or more of the exposed section of the shales the pyrite is found in considerable abundance. It occurs in different forms; as small crystals and grains disseminated through the mass, as nodular aggregates from the size of a walnut up to 3 or 4 inches in diameter, and as one or more bands constituted of coalescent aggregates which are not well enough exposed in the bank to show their thickness and continuity.

The latter are found near the water level of the adjacent creek and were partly submerged and partly covered over with talus from the adjacent bank. The nodules are in part solid masses of pyrite and in part consist of an outer shell of pyrite enclosing a core of shaly matter with a larger proportion of celestite. The latter occurs in small bladed crystals intergrown so as to form a somewhat coherent though fragile mass. The individual crystals are rarely more than one-half of an inch long and very thin and delicate. Their identity was established by qualitative chemical tests. The presence of barytocelestite, a mixture of strontium and barium sulphates in the Rondout waterlime to the east of Schoharie village is mentioned by Grabau¹ and earlier by John Gebhard.² It is possible that the celestite from this locality may also carry some barium, but its presence has not been determined. An analysis of the pyrite found in the nodules and larger aggregates was made by H. F. Gardner of the Museum staff.

S.....	42.75
Fe.....	39.74
SiO ₂	10.04
Al ₂ O ₃	.82
Insol.....	2.14
As.....	.00

Lime, magnesia, barium and strontium were present but not determined.

References

- Beck, Lewis C. *Mineralogy of New York*, 1842, p. 387
- Brinsmade, Robert B. *Pyrites Mining and Milling in St Lawrence County, New York. The Mineral Industry*, v. 14, 1906, p. 525-27
- Buddington, A. F. *Report on the Pyrite and Pyrrhotite Veins in Jefferson and St Lawrence Counties, New York. N. Y. State Defense Council Bul. 1*, 1917
- Newland, D. H. *Pyrite in Northern New York. Eng. & Min. Jour.*, Dec. 1, 1917
- . *The Zinc-Pyrite Deposits of the Edwards District. N. Y. State Defense Council Bul. 2*, 1917
- Smyth, C. H. jr. *On the Genesis of the Pyrite Deposits of St Lawrence County, N. Y. N. Y. State Mus. Bul. 158*, 1912, p. 143-82
- Vogel, Felix A. *Pyrites Mining and Milling in St Lawrence County, New York. The Mineral Industry*, v. 16, 1908, p. 845-51

QUARTZ

Quartz, the oxide of silicon, is one of the most abundant minerals in nature. It constitutes largely the mass of sandstone, quartzite, river and beach sands, and is an important component of granite, gneiss, many schists and other rocks. It is a common vein mineral,

¹ N. Y. State Mus. Bul. 92, 1906, p. 360-61.

² Amer. Jour. Sci., v. 28, 1835, p. 172.

occurring either alone or as gangue for ores. In the form of chert, a micro-crystalline variety, it is associated with some limestones. Quartz possesses qualities of hardness, toughness and resistance to chemical change matched by relatively few other minerals.

Despite the abundance of materials containing quartz in large amounts, the supplies of high-grade silica adapted to certain important industrial uses are not so common but that they possess extensive interest and value. One of the more persistent impurities of great importance in determining the commercial availability of deposits is iron which may always be counted upon as present in one form or another. It may be carried by finely divided iron oxides, or by admixture with some iron-bearing silicate like biotite, hornblende or pyroxene.

Uses. The manufacture of glass requires large amounts of high-grade quartz. To be suitable for most kinds of glass, the material should contain 98.5-99 per cent of silica as a minimum. The restrictions with regard to iron are rigid; for plate and window glass the usual limit is 0.2 per cent ferric oxide, equivalent to 0.14 metallic iron, and for optical glass nothing more than a trace is allowable. A granular material is best adapted to this purpose, and consequently sands and loosely textured sandstones easily reducible to granular state are mostly used. Sands that are not suitable in their natural state may sometimes be beneficiated by washing and screening. The size should be also fairly uniform and not too coarse; a sand that ranges from 20 to 50 mesh is preferred.

Pottery manufacture also requires a high-grade quartz low in iron. Vein quartz or a micro-crystalline quartz something like flint is used and has to be finely ground.

The manufacture of silicon and ferro-silicon has become quite an important industry in the State, and has developed a local market for material suited to the purpose. A silica content of 96 to 97 per cent is required; the limitations otherwise are not particularly rigid. A quartz sandstone or quartzite is employed by most of the plants in the State and there are abundant supplies to be had in the Potsdam and other formations.

Quartz is an important refractory material in metallurgy. It is employed in the form of quartzite and quartz schist (ganister) for the lining of shaft furnaces and as sand (fire sand) for open-hearth furnaces, ladles etc.

Among the other uses of quartz are as an abrasive, wood-filler and as an ingredient of paints. For sand-paper vitreous or vein quartz is crushed and sized. The purity is not so important, but the quartz

should not be too much discolored. In paint and wood-filler the same kind is employed in finely pulverized condition.

A special investigation of the high-silica materials of the State was carried out in 1918 by R. J. Colony, and the results published as bulletin no. 203,204 of the New York State Museum.

Quartz sands. The sand deposits are described under a separate title, and need not be given special attention here. It may be remarked that the deposits are mainly of glacial origin and do not rank very high in silica content, being mostly mixtures of quartz with clay and various rock materials, so that they are seldom adapted to the employments above described. The best materials are the beach sands represented in the Oneida lake region and on the north shores of Long Island. The former locality has supplied considerable quantities of quartz sand for window-glass manufacture and fire and core sands.

Sandstones and Quartzites. Some of the bedded formations contain sandstone members that are high in quartz content. These include granular more or less open textured rocks, which belong to the class of sandstones in the strict sense, and rocks which have been cemented and filled with a secondary silica deposit forming a solid mass of quartz, or a quartzite.

One of the more widespread sandstones that often carries a high quartz content is the Potsdam. This outcrops extensively on the northern, eastern and southern borders of the Adirondacks. In some places it is a hard, vitreous quartzite and in others it has the open texture of sandstone. The beds range from a few inches to two or three feet thick and are white, gray or pink in color. The areas on the north side of the Adirondacks, particularly around Moira and Bangor, Franklin county, seem to contain the highest silica material, which has been used locally for glass manufacture to some extent. On the east side at Port Henry and farther south at Fort Ann there are exposures of fairly pure quartzite. On the south side of the Adirondacks the Potsdam occurs in minor areas of which one at Keck Center, Fulton county, yields a white granular sandstone, with 96 to 99 per cent silica, that is used for ferro-silicon manufacture.

The Oriskany sandstone of the central part of the State has beds of rather coarse, white, sugary quartz rock that is high in silica. There are good exposures at Oriskany Falls, Oneida county, and near Union Springs, Cayuga county.

The Shawangunk grit is a coarse quartzite or conglomerate that outcrops in Ulster, Orange and Sullivan counties. It is quarried

for millstones, and at one time also was worked for glass material, the latter having been obtained near Ellenville.

The Poughquag quartzite, which occurs in the Highland region and north of there, contains beds which are practically pure quartz. It is an extremely hard and tough material, owing to its thorough impregnation by secondary silica which has converted the mass into the condition almost of vitreous quartz. By reason of these qualities it should be well adapted for the lining of tube mills and is also probably suitable for chemical and metallurgical uses.

Vein quartz. Vitreous or vein quartz occurs in many places in the Adirondacks and in the Highlands, particularly on the margins of granitic intrusions. No very large veins are known, although occasionally they attain workable dimensions. A number of occurrences near Fort Ann and Port Henry once supplied material for making wood filler which was prepared in a mill at Fort Ann. Some quartz has been shipped to sand-paper manufacturers from this region. The largest output of vein quartz has come from near Bedford, Westchester county, where it is associated with the pegmatite of that locality. The quartz is found in segregated bodies practically free of admixture and also associated with feldspar as a constituent of the pegmatite. The product of the quarries is employed for wood filler and silicate paint.

SALT

Salt has a prominent place in the list of New York's mineral products. This position it has maintained for a long time, as salt making was one of the early industries that had much to do with the pioneer settlement and trade development of the interior of the State.

The importance of the salt industry may be the better appreciated when it is considered that the deposits are widely distributed, occurring within an area which has not yet been definitely delimited but which certainly covers several thousand square miles — constituting a resource scarcely to be measured in terms of present day or nearby prospective consumption — and that in many places the deposits are easily reached by wells or shafts located close to some of the main railroad lines or on natural waterways. The situation of the deposits with reference to the market is an important economic factor; they are the most easterly of all those in the country, and thus have a natural advantage in the seaboard trade, as well as in the interior of New England, New York and Pennsyl-

vania with their large industrial centers. The chemical industries in this section afford one of the principal outlets for the product.

Historical. Salt making in New York was carried on in a small way during the colonial days. The earliest mention of the occurrence of salt within the present state limits is found in the Jesuit "Relations." Some missionaries from the Canadian settlements along the St Lawrence river visited the neighborhood of Onondaga lake in the middle of the 17th century and reported upon the remarkable saline springs there which had long been known to the Indians. Both the natives and occasional traders collected salt from this source before the Revolution had opened the lands to white settlers.

The present industry may be said to have been started in 1788 when the State secured title to the lands on the shores of Onondaga lake "for the common benefit of the people of the State of New York and the Onondagas for the purpose of making salt." In the same year, or according to some authorities, in 1789 salt manufacture was begun at Salt Point (later the village of Salina) in an open kettle, with the use of brine dipped from a shallow opening dug in the ground. This primitive undertaking was started by Asa Danforth and Comfort Tyler. In 1793 a regular salt works, consisting of an arch with four potash kettles, was built by William Van Vleck and Moses DeWitt. The State assumed control of the salt industry in 1797 when the Legislature passed laws regulating the employment of brines on the Onondaga Salt Springs Reservation and appointed a superintendent to take charge on the ground. The brine was pumped by central stations and supplied to the individual evaporating plants who were taxed upon the output to repay the cost of pumping and supervision. The State did not relinquish its control of the natural brines until 1908 by which time the production in the Onondaga reservation had declined to small proportions by reason of competition with the salt made from the richer artificial brines secured in the rock salt district. Solar evaporation in the vicinity of Syracuse began in 1821; it rapidly became established in favor and for several years it has been the sole method of making salt from the natural brines.

The occurrence of rock salt in New York was not established until 1865 when the first discovery was reported in the vicinity of Vincent, Ontario county. No use was made of the deposit, and it was only in 1881 that the rock salt beds began to be exploited. An evaporating works was put in operation in that year near Wyoming, Wyoming county, deriving its supply of brine from the bed of rock salt which had been found in the course of "wildcat" oil explorations

in 1878. The bed at that place was encountered at about 1270 feet and was 70 feet thick. In 1881 rock salt was discovered in Warsaw, 5 miles south of the Pioneer well near Wyoming. The record of the boring showed 80 feet of salt, with an additional 31 feet of mixed salt and shale, beginning at 1520 feet depth. The continuation of the beds to the south was established by a well at Rock Glen 3 miles from Warsaw which found the salt at 2015 feet; another at Silver Springs, 2 miles farther south, showing salt at 2224 feet; and at Gainesville creek and Bliss still farther away. Evaporating works were built at Warsaw, Rock Glen and Silver Springs. In the Genesee valley the first successful well was drilled in 1883 near the present shaft of the Retsof mine, and within the succeeding few years the occurrence of salt was reported at a number of other localities in the valley between the north and south boundaries of Livingston county. A well at Ithaca on the south end of Cayuga lake in 1885 encountered 248 feet of salt at depths below 2244 feet. Evaporating plants were built at Ludlowville and Ithaca. In 1893 the Glen Salt Co. put down a well at Watkins at the head of Seneca lake which was used as a source of brine. In 1888 the Solvay Process Co. began the drilling of wells in the Town of Tully, 17 miles south of Syracuse, and by 1896 had put down 41 wells to the salt which was encountered at depths of about 1200 feet. Fresh water is conducted from the Tully lakes into the wells and after saturation is pumped and transported by pipe line to the large soda works at Solvay. The most easterly point at which the rock salt is found is at Morrisville, Madison county, where a well drilled in 1886 encountered a bed 10 to 12 feet thick at 1259 feet.

The first mine shaft that reached the salt was put down by the Retsof Mining Co. at Retsof, Livingston county. It was started in 1884 and bottomed the following year at a little over 1000 feet. The Greigsville Mining Co. put down one at Greigsville, just west of the Retsof shaft. The Lehigh Mining Co. opened a mine $2\frac{1}{2}$ miles south of LeRoy, Genesee county, and the Livonia Salt Mining Co. at Livonia, Genesee county, which have since been abandoned. The Sterling Salt Co. started mining at Cuylerville, Genesee county, in 1906. The last mine shaft to be completed is that of the Rock Salt Corporation on Portland Point north of Ithaca, which was bottomed in 1917.

Occurrence of salt. Natural brines are found in a number of places and under varied geological conditions. Weak salines occur quite generally in the Medina sandstone; Hall has reported natural licks or springs at 15 localities within the Medina formation from

Cayuga county to Niagara county. Salt was made in the early days at Kendall and near Medina, Orleans county, and at Somerset, Niagara county. Brine springs are known also along the outcrop of the Salina shales, as at Montezuma, Cayuga county, and in the towns of Savannah and Clyde, Wayne county, where evaporating works were once operated. The Hamilton and Portage shales of western New York are sources of weak brines. Most interest, however, centers about the occurrence on the Onondaga reservation where salt manufacture had its inception and has been carried on uninterruptedly down to the present time.

The Syracuse brines are stored in sands and gravels that underlie the valley of Onondaga creek and Onondaga lake. These loose materials are probably of glacial origin, a part of the morainal accumulations in the vicinity, and occupy a channel or basin hollowed out in the Salina beds, that is the soft Camillus and Vernon shales. The buried channel follows the course of the surface contours marking the wider Onondaga valley. The gravels and sands extend to depths of several hundred feet at the foot of Onondaga lake. Originally the gravels were saturated with brine practically to the surface, so that it was only necessary to dig a shallow pit or hole to collect it. As the use increased it was found that the shallow brines became weakened, and then wells were put down which were gradually extended until the maximum depth of about 400 feet was attained. The present supplies come from wells 200 to 400 feet deep. There has been a noticeable decrease in the salinity of the brine with the continued pumping. It is generally held, and no doubt properly so, that the brine is supplied by leaching of the rock salt beds to the south. The flow of water is opposite to the inclination of the beds, which is to the south and about 50 feet or so to the mile, but there is a rise in the surface contours in the same direction sufficient to give the necessary hydraulic head.

The rock salt beds supply all of the salt now produced with the exception of the relatively small quantity made by the solar process at Syracuse. The beds are assigned by geologists to the Salina stage of the Silurian, representing the equivalent practically of the Onondaga Salt group of the early reports of Hall and Vanuxem. The Salina is mainly a shale formation, but carries layers of thin limestone at the top (Bertie) besides gypsum and salt which occur in the gray and drab shales of the Camillus formation. Its lower member is made up of the Vernon red shale. The outcrop of the beds extends in an east and west belt from Albany county to the

Niagara river. The belt east of Oneida county is thin and follows the range of hills in an east-southeast direction parallel with the Mohawk. With the gradual thickening of the beds and flattening of the topography the outcrop widens out rapidly as it approaches the Oneida lake section becoming 10 miles wide in Onondaga county and nearly 20 miles on the line of Cayuga lake where the extreme dimensions are reached. Thence west to the Niagara river the outcrop forms a nearly straight belt 7 to 10 miles wide.

Our knowledge as to the horizon of the salt in the succession is derived entirely from the records of well borings and the few shafts that have been put down to the beds. The data supplied by the wells are not altogether reliable as most of the borings were made by oil well rigs, a method that does not admit of accurate records. The salt itself is not encountered except at some distance to the south of the outcrop where the covering protects it from the seepage of surface waters.

In exploration the hard cherty Onondaga limestone following the black Marcellus shale is used as a bench mark by which to locate the position of the salt. The top of the limestone is taken rather than the base, as the succession below is variable and the line between the Onondaga and Oriskany sandstone where present or of the Onondaga and Bertie waterlime is not so easily established. It would appear from the various well logs that the salt lies at varying intervals from the bench mark, ranging from a minimum of about 350 feet to a maximum of 900 feet or so. In the same locality within short distances the interval may also show considerable variations, as in the group of wells at Tully where the salt lies anywhere from 492 feet to 556 feet below the top of the Onondaga. The cherty limestone varies from 60 feet thick in the eastern to 150 feet in the western part of the salt district.

There seems to be no constant position for the salt, further than that it lies in general within the gray shales between the Bertie waterlime above and the Vernon shales below (see diagram p. 95). Its variability in this respect agrees with the gypsum which likewise shows a considerable vertical range. The question arises whether the salt is not actually in the form of lenses rather than beds, analogous to the gypsum which has been quite clearly shown to be in attenuated lenses that succeed each other along the strike and dip of the strata, in places separated by considerable intervals and again overlapping each other. The writer is inclined to view the rapid changes in the horizon, thickness and number of the salt beds as shown in the well records from different localities to be indicative of such structure.

The salt attains its maximum thickness apparently in the eastern section, on the extension of the dip south of the Onondaga-Cayuga county part of the Salina outcrop. This is indicated by the actual records of the wells drilled to the salt and indirectly by the relative magnitude of the gypsum beds which are exposed within the Salina belt from Madison to Erie counties. Inasmuch as the gypsum represents one element of the series of original deposits from the Salina sea or salt basin, in which it may be believed that the relative proportions of mineral ingredients were fairly uniform for the entire area of evaporating waters, there ought to be some balance between the volumes of the two materials, unless exceptional conditions obtained during the period of evaporation or the original relations have been destroyed by subsequent attack of ground waters on the beds. There is nothing to show that the salt beds have undergone marked rearrangement resulting in any considerable increase or shrinkage locally in their dimensions except for the wastage that has taken place along the outcrop.

In the series of Tully wells, no. 2, group A, is reported by Luther to have been drilled through four salt beds, 24, 74, 36 and 60 feet thick respectively, in order from top to bottom and making an aggregate of 204 feet.

At Ithaca a well drilled in 1885 showed a total thickness of salt, according to Prosser, of 248 feet, divided into seven seams. A test well on Portland Point, 6 miles north of the Ithaca well, penetrated three beds, an upper of 17, a middle bed of 27 and a lower bed of 72 feet, with a parting of shale 27 feet thick between the upper and middle beds and another shale parting 6 feet thick between the middle and lower beds.

At Watkins, at the head of Seneca lake, a well was drilled 102 feet into the salt. There is no record of the total thickness.

In Livingston county the several salt shafts show a thickness of from 50 to 80 feet of salt including impure beds of shaly material.

In the Oatka valley the salt beds have a thickness of 75 to 80 feet where they have not been leached.

The data of wells put down by the ordinary oil-rig, which is the method employed in drilling brine wells, are not to be regarded as very accurate and some allowance must be made therefore in comparing the records with reference to the salt. This applies both to the dimensions and the interpretation of the character of the beds. In some wells, doubtless, the measurements include beds which are really shale impregnated to a greater or less extent with

salt, as it is extremely difficult to discriminate between a bed of that kind and an alternating series of salt and shale beds.

Mining of salt. The production of salt by mining conducted through shafts sunk to the beds has been in progress in New York since 1885, when the first shaft of the Retsof Mining Co. at Retsof was bottomed. In the following few years other shafts were put down; one $2\frac{1}{2}$ miles south of LeRoy, Genesee county, by the Lehigh Salt Mining Co.; one at Livonia, Livingston county, by the Livonia Salt & Mining Co.; and one at Greigsville, Livingston county, by the Greigsville Salt & Mining Co. In 1906 the Sterling Salt Co. completed a shaft at Cuylerville, Livingston county. The last shaft to be put down is that of the Rock Salt Corporation at Portland Point on Cayuga lake which was completed early in 1918.

Underground mining has an advantage over the method of extraction by brine wells on the basis of production costs. Its disadvantage inheres in the impure quality of the product, which necessarily contains more or less of the admixed calcium and magnesium compounds, which in the process of brine evaporation are largely removed. Rock salt, however, finds extensive uses, and the consumption has grown more rapidly of late years than of evaporated salt.

The mining operations are not essentially different from those employed in working a flat coal seam on the room-and-pillar method. Main galleries are extended east and west which serve as permanent haulage ways, and then headings are driven at right angles, at regular intervals, dividing off the ground into panels. The pillars measure 30 feet on the side and are spaced 30 feet apart, in the usual practice. This results in the removal of 75 per cent of the actual working thickness. In the mines in Livingston county, the only ones that have been extensively worked, the portion of the bed suitable for mining ranges from 6 or 7 feet to 12 feet thick.

The salt is broken by drilling a series of holes with rotary auger drills and charging the holes with dynamite. In the ordinary run a hole is 6 to 7 feet in depth and can be drilled in about 3 minutes. The auger is $1\frac{1}{2}$ inches diameter. Electric power is now used. It would seem practicable to undercut the salt, as is done in mining soft coal, but the trials that have been made with coal-cutting machines have not been successful. The salt is said to possess a degree of toughness that greatly lowers the efficiency of such machines even to make their use impracticable, at least in their present forms.

The broken salt is loaded on to cars which are drawn by mules to the main haulage ways; then they are made up into trains to be hauled

by electric locomotives to the shaft. The steel cars hold 3 tons each. These are loaded both by hand and by automatic shovels, the use of the latter having been taken up quite recently.

At the shaft the cars are run on to cages and hoisted to the top of the breaker. There are two hoisting compartments in each shaft, the cages being operated in balance, and the usual rate is about a car each minute, the distance to the top of the breaker being 1150 feet. At the breaker the car is dumped into a bin from which it goes through the process of crushing and screening to provide the various sizes in demand. These include lump salt, large and small and 5 graded sizes, ranging from three-quarters to one-sixteenth of an inch in diameter.

During the last several years the only active mines have been those of the Retsof Mining Co. and the Sterling Salt Co. The shaft at Portland Point has not been equipped for production.

Manufacture of salt from brine. The making of salt by evaporation of brines, or water solutions of salt, is the really essential branch of the industry, so far as concerns the majority of uses. Brine salt may fill the place of rock salt in practically all applications; the relative cheapness of the latter is the principal factor in the development of the market for mined salt. It is only by evaporation that the impurities which are invariably present in the natural salt or brines may be removed and the product made fit for human consumption. These impurities consist largely of calcium and magnesium compounds, of which the latter are obnoxious because of their bitter taste and medicinal qualities. Calcium chloride has a great affinity for water and causes the salt to cake when exposed to the air.

The methods of salt manufacture that have been employed in New York State include the following: (a) solar evaporation; (b) evaporation by direct heat in open kettles or pans; (c) evaporation by steam with jacketed kettles or grainers; (d) evaporation by steam in vacuum pans.

Solar evaporation is the process in use for the natural brines found on the old Onondaga reservation near Syracuse. It was first employed in 1821, previous to which time the salt was made in open kettles by direct heat. Both methods were in use until a few years ago, when the kettle process was discontinued, and all the salt now made at Syracuse consists of the coarse solar variety. The evaporation is carried out in shallow wooden vats, of which one kind known as aprons in which the brine is only about one-half of an inch deep performs the first step in the concentration, raising the salinity to a

point where the gypsum is about to precipitate. The brine is then drawn into vats about 6 inches deep in which the gypsum or "lime" deposits and the solution becomes saturated with respect to the salt. This solution is called "pickle" and goes to the salt rooms where the final stage is accomplished. The salt crystals are raked from the floor of the rooms about three times a season which in a good year lasts from the middle of March to the middle of November. The vats are protected against rain by covers or roofs mounted on a wooden framework so as to be moveable. Some idea of the size of the industry in the flourishing days may be had from the statement of the state superintendent of the Onondaga Salt Springs in his report for 1894 that about 45,000 covered vats, each 16 by 18 feet, were then in use. This implies an evaporating surface of 12,960,000 square feet. The estimated investment represented by these structures, with the storehouses and mills, at that time was placed at \$2,750,000. The crop of the solar salt in 1894 was 2,355,394 bushels or 471,079 barrels.

The artificial evaporation of brines is now conducted by open pans, by grainers and by the vacuum pan. Open kettles heated by fire or by steam coils are no longer in use.

Open pans are to be seen in only a few plants, as they have largely been superseded by grainers which are more economical of heat and in which the process of evaporation is carried on with less frequent interruptions. The high temperatures attained by direct fire are likely to cause warping of the pans and buckling of the arches, necessitating considerable expense for repairs. They have an advantage over grainers, however, in that the evaporation can be hastened by rapid boiling which leads to finer crystals, as the quicker the process of precipitation, after the saturation point is reached, the finer will be the crystal particles. On the other hand they require more attention.

The pans are made of boiler iron and set in brick arches with fire grates at one end from which flues conduct the heated gases under the whole length of the pans. These latter are about 100 feet long and 25 to 30 feet wide, divided into a front and back section by a transverse partition. The brine after settling and liming which remove the iron and mechanical impurities is conducted into the back pan where it is preheated and then siphoned into the front pan in which the final evaporation is carried out. When the salt has formed a sufficient deposit in the pan it is raked out and additional brine added. From time to time the operation is stopped to remove the bittern and scale the pan which becomes encrusted with a deposit of gypsum.

Grainers are now employed in practically all of the plants engaged in making salt for domestic uses. They are seldom used alone, but most often in conjunction with open pans or with vacuum pans. The grainer consists of an open vat, 100 feet or more long, 12 to 15 feet wide, and about 2 feet deep, built of iron alone or lined with concrete or wood with a series of iron pipes, running the length of the vat and placed about a foot from the bottom, in which the steam is supplied. The brine is preheated outside of the grainer by waste steam. The process of salt making employs the principle of fractional crystallization, whereby the concentration of the brine is kept above the point of saturation for the more soluble chlorides of magnesium and calcium; as the bittern becomes charged with these it is drawn off and wasted or employed in a second series of grainers for making an inferior grade of salt. The salt particles from the grainer are often composed of several small crystals, giving a coarser size than with the open pan. The salt is removed by mechanical rakers which operate continuously or by hand. Operations have to be suspended at intervals to scale the walls and pipes, the period of evaporation ranging from a few days to several weeks, depending on the amount of calcium sulphate in the brine.

Vacuum pans, technically, are superior to all other mechanical devices for evaporating salt, as they are most economical of heat and require less attention in proportion to the quantity of product. Their main drawback is the high cost of installation. As in use in New York they consist of a vertical cyclinder, terminated at each end by a cone, built of sheet iron or steel. The steam for heating is supplied to a belt within the middle or the cylindrical part of the pan, in which is placed a series of copper tubes immersed in the brine or through which the brine is pumped. Vacuum is maintained by means of a pump connected with the top cone, assisted by rapid condensation of the steam as it comes off at the same place. The salt as it crystallizes falls to the bottom and is discharged through a pipe, after which it is drained by a centrifugal. A vacuum of about 28 inches is maintained in the pan, if operated as single effect. At one plant there are four pans connected to work as a quadruple effect, in which the brine is maintained under a vacuum of about 13 inches for the first, 20 inches for the second, 26 inches for the third and 28 inches for the fourth. Boiling takes place at progressively lower temperatures with increase of vacuum. The pans have to be boiled out every day or so and scaled at intervals of a few months.

List of brine plants. The manufacturers of salt in the Syracuse district, using the solar process, include the following who were in operation in 1916: J. L. Cady, P. Corkings, Draper & Porter, Empire Coarse Salt Co., Thomas K. Gale, Geddes Coarse Salt Co., Highland Solar Salt Co., P. J. Johnson, Cady & Johnson, Salina Solar Coarse Salt Co., Turk's Island Coarse Salt Co., Western Coarse Salt Co., John White & Son, Salt Springs Solar Coarse Salt Co. All the solar salt is marketed through the Onondaga Coarse Salt Association. It is sold in seven sizes, of which six represent the different sizes of salt crystals, separated by screening, as follows: Diamond C, BC, Standard, Diamond F, BF, and 6-mesh BT. The finest size is 8-mesh, which is crushed and passed through a screen of eight meshes to the inch.

The list of manufacturers of artificially evaporated salt for recent years has included the following: International Salt Co., with works at Myers, Ithaca and Watkins; Worcester Salt Co., Silver Springs; Rock Glen Salt Co., Rock Glen; Eureka Salt Co., Saltvale; Remington Salt Co., Ithaca; Watkins Salt Co., Watkins; Genesee Salt Co., Piffard; LeRoy Salt Co., LeRoy; Solvay Process Co., Solvay.

Production. The record of salt production in New York State is practically complete from the start of regular operations in 1797. In that year the output was 25,474 bushels, or 5095 barrels. By 1828 the production had grown to over 1,000,000 bushels, or 200,000 barrels, and by 1849 it passed 1,000,000 barrels. In the succeeding 30 years it made slow growth; in 1880 when the manufacture of salt from artificial brines was about to begin it had increased only to 1,599,750 barrels. The production since then has made rapid strides. Altogether the product of brine and rock salt in the State in the period 1797-1918 has amounted to the total of 323,870,546 barrels.

The production of salt by grades for the last three years is shown in the tables below:

Production of salt by grades in 1916

GRADE	BARRELS	VALUE	VALUE A BARREL
Common fine.....	1 694 943	\$828 617	\$.48
Common coarse.....	267 421	153 844	.57
Table and dairy.....	1 308 529	940 969	.71
Solar.....	249 728	110 505	.44
Other grades <i>a</i>	10 567 129	1 664 863	.16
	14 087 750	\$3 698 798	\$.26

Production of salt by grades in 1917

GRADE	BARRELS	VALUE	VALUE A BARREL
Common fine.....	I 804 721	\$1 331 221	\$.73
Common coarse.....	252 114	218 747	.86
Table and dairy.....	I 458 165	I 413 905	.96
Solar.....	130 914	91 978	.70
Other grades <i>a</i>	II 811 722	2 315 862	.19
	15 457 636	\$5 371 713	\$.34

a Includes rock salt, salt in brine used for alkali manufacture, agricultural salt and small amounts of brine salt for which the uses were not specified in the returns.

Production of salt by grades in 1918

GRADE	BARRELS	VALUE	VALUE A BARREL
Common fine.....	I 581 671	\$1 517 725	\$.96
Common coarse.....	215 229	240 388	1.11
Table and dairy.....	I 770 885	I 964 402	1.11
Solar.....	118 029	125 107	1.06
Other grades <i>a</i>	II 532 257	3 489 245	.30
	15 218 071	\$7 336 867	\$.48

a Includes rock salt, salt in brine used for alkali manufacture, agricultural salt and small amounts of brine salt for which the uses were not specified in the returns.

Salt production in New York

YEAR	BARRELS	YEAR	BARRELS
1797.....	5 095	1814.....	59 000
1798.....	11 986	1815.....	64 412
1799.....	8 541	1816.....	69 731
1800.....	10 000	1817.....	81 731
1801.....	12 400	1818.....	81 308
1802.....	15 000	1819.....	109 675
1803.....	18 000	1820.....	91 666
1804.....	20 000	1821.....	105 210
1805.....	30 814	1822.....	96 312
1806.....	24 515	1823.....	145 398
1807.....	35 090	1824.....	163 327
1808.....	63 924	1825.....	151 441
1809.....	25 656	1826.....	162 205
1810.....	90 410	1827.....	196 682
1811.....	40 000	1828.....	232 178
1812.....	44 202	1829.....	225 856
1813.....	45 200	1830.....	287 089

Salt production in New York — (*concluded*)

YEAR	BARRELS	YEAR	BARRELS
1831.....	302 807	1875.....	1 435 909
1832.....	330 597	1876.....	1 078 553
1833.....	367 729	1877.....	1 285 597
1834.....	388 650	1878.....	1 435 239
1835.....	241 973	1879.....	1 664 432
1836.....	382 572	1880.....	1 599 750
1837.....	433 457	1881.....	1 583 447
1838.....	515 007	1882.....	1 668 180
1839.....	572 944	1883.....	1 619 486
1840.....	524 261	1884.....	1 788 454
1841.....	668 153	1885.....	2 304 787
1842.....	458 781	1886.....	2 431 563
1843.....	625 500	1887.....	2 353 560
1844.....	860 111	1888.....	2 318 483
1845.....	752 472	1889.....	2 273 007
1846.....	767 770	1890.....	2 532 036
1847.....	792 271	1891.....	2 839 544
1848.....	947 425	1892.....	3 472 073
1849.....	1 016 714	1893.....	5 662 074
1850.....	853 784	1894.....	6 270 588
1851.....	922 823	1895.....	6 832 331
1852.....	984 507	1896.....	6 069 040
1853.....	1 080 905	1897.....	6 805 854
1854.....	1 160 669	1898.....	6 791 798
1855.....	1 216 577	1899.....	7 489 105
1856.....	1 199 362	1900.....	7 897 071
1857.....	862 425	1901.....	7 286 320
1858.....	1 406 678	1902.....	8 523 389
1859.....	1 378 854	1903.....	8 170 648
1860.....	1 118 649	1904.....	8 724 768
1861.....	1 440 078	1905.....	8 575 649
1862.....	1 810 775	1906.....	9 013 993
1863.....	1 568 477	1907.....	9 657 543
1864.....	1 475 777	1908.....	9 005 311
1865.....	1 277 186	1909.....	9 880 618
1866.....	1 431 701	1910.....	10 270 273
1867.....	1 519 103	1911.....	10 083 656
1868.....	1 733 323	1912.....	10 502 214
1869.....	1 732 447	1913.....	10 819 521
1870.....	1 749 623	1914.....	10 389 072
1871.....	1 674 991	1915.....	11 095 301
1872.....	1 586 185	1916.....	14 087 750
1873.....	1 492 071	1917.....	15 457 636
1874.....	1 205 860	1918.....	15 218 071

References

- Beck, Lewis C. Mineral Springs. Mineralogy of New York. 1842
- Bishop, I. P. Salt Wells of Western New York. N. Y. State Geol. 5th Ann. Rep't, 1886
- . Salt Industry of Central New York. N. Y. State Mus. 45th Ann. Rep't, 1892
- Hall, James. Geology of New York. Report on Fourth District. 1843

- Luther, D. D.** Geology of the Livonia Salt Shaft. N. Y. State Geol. 13th Ann. Rep't, 1894.
- . Brine Springs and Salt Wells of New York and Geology of the Salt District. N. Y. State Geol. 16th Ann. Rep't, 1899.
- Merrill, F. J. H.** Salt and Gypsum Industries of New York. N. Y. State Mus. Bul. 11, 1893.
- Vanuxem, L.** Geology of New York: Report on Third District. 1842.

SAND AND GRAVEL

Sand and gravel deposits are widely distributed; almost every town or hamlet within the State has its local beds of these materials from which supplies are obtainable for the ordinary demands of building and engineering construction. The production thus represented is enormous in the aggregate, but is divided among so many widely scattered and more or less fugitive operations that it can scarcely be measured with accuracy. The product under such circumstances may bear only a nominal value, represented mostly by the cost of digging or possibly of washing and screening as well. On the other hand the marketing of sand and gravel in the larger cities is a business organized on a stable and permanent basis, involving considerable capital investment that has to be considered in the costs of production and selling prices for the output. Thus a large proportion of the total value of building sand that is sold annually is represented by the output of a relatively small number of producers in Nassau county who are tributary to the New York City market.

Besides building sand the State contains molding sands, glass sands and sands suitable for other purposes of metallurgy and manufacturing. The molding sand business is especially important; large quantities of the finer grades used in making small iron castings and in brass and aluminum work are shipped from the Hudson valley. Glass sand occurs in the vicinity of Oneida lake and on the shores of Long island and it has been obtained in past years by crushing of certain pure quartz sandstones like the Shawangunk grit. Fire sands and core sands are refractory quartz sands that occur in a few places. Polishing sand used on rubbing beds of stone-cutting establishments, engine sand for railroads and filter sand for municipal filtration plants are also obtained from local deposits.

Distribution. Most of the unconsolidated surficial sands are of glacial origin. Some were laid down under the ice as part of the ground moraine; others as accumulations at the margin of the glacier of the materials embedded in or transported upon the ice. In the latter class of deposits the sorting action of water is apparent in

the arrangement of the materials, as they show a more or less stratiform or bedded structure which is absent from till of the ground moraine. A third method of occurrence is represented by the sands and gravels along the beaches of the glacial lakes that came into existence in the closing stages of the Pleistocene after the withdrawal of the ice. Here the materials are characterized by a uniformity of physical features by reason of the efficient sorting action of the shore waters that is comparable to that of beach sands along our present coasts. Glacial Lake Iroquois, which occupied the basin of Lake Ontario but spread far beyond the present limits of its waters, has the largest of these beach deposits. In the Hudson and Champlain valleys the glacial waters also rose to high levels and have left behind a series of bedded sands, gravels and clays which are easily to be discriminated from the morainal and outwash deposits directly contributed by the ice.

In the beaches of Long island and Staten island are found more recent deposits of sand and gravel that have economic importance. Their materials, however, are largely derived from the glacial moraines which extend across the islands from the Connecticut to the New Jersey mainland and which mark the most southerly limit of the Pleistocene ice sheet. As compared with the morainal sands they are much better graded both in size and character of material, and their field of usefulness is much increased. Smaller beaches of present-day formation occur on the shores of the interior lakes.

Building sand. In this class are included the loose sands and gravels employed in making mortar, concrete or artificial stone for engineering work and buildings. A large variation in composition and physical properties may be found in such sands, and in fact almost any deposit that contains a fair percentage of hard particles, not too fine in grain, whether of quartz or of undecomposed rock, may be employed where the conditions of service are not very rigid. The resources consequently are more extensive than of sands for special employment, and little attention has been given heretofore to their investigation.

It is to be noted in this connection that sands are actually an important factor in determining the quality of the concrete for which they are used, and the tendency in engineering work is toward the careful selection of both sand and the coarser aggregates. To be suitable for dependable structures a sand should be practically pure quartz, free of clayey admixture or of shale particles which shrink or swell under changing atmospheric conditions. The texture of sand is also important but the requirements in this respect vary

with the conditions of use. The testing of sands has become an important function of engineering laboratories, with the growing recognition of the need for certain standards, just as in reference to other uses of the material. The consequence is that the available supplies of high-grade sands are nowhere so extensive as might be surmised from the wide presence of sand deposits and in some considerable areas they are practically absent. In the last few years there has taken place a marked change in the productive industry by reason of the centralization of operations in certain localities where the best materials are found; much of the product now undergoes preparation by washing or screening which necessitates mechanical installations and lends a permanency to the enterprises which they formerly lacked.

The largest market for building sands in the State is New York City. More than one-half of the quantity and value of the annual product is probably used in the metropolitan district. The supply is obtained from different sources, mainly on tidewater, of which the more important are on the north shore of Long island, principally in Nassau county. The sands are obtained from the beaches and from the beds which are exposed in the series of bluffs that front the beaches, showing a vertical section of sands, gravels and boulders of 100 feet or more. The beaches represent the resorted materials of these beds which are of Pleistocene age and partly of marine and partly of morainal character. The beach sand is obtained by dredging and is sufficiently clean and sized to be marketable as it comes. The sand from the beds is excavated by steam shovels working against the face of the bank and is mostly prepared in washers which afford different sizes ranging from gravel to fine sand. Barges are used for transporting the sand which is used in building and construction work in New York and vicinity. The larger plants are those of the Goodwin-Gallagher Sand and Gravel Corporation at Port Washington and Northport, Phoenix Sand and Gravel Co., Roslyn, and O'Brien Brothers, Inc., Hempstead. Special grades of sand that are obtained here include fire and core sand, engine sand and filter sand.

In the Hudson valley, north of the Highlands, a series of terraced beds composed of clay, sand and gravel rise from the water's edge to levels that gradually increase to the north. The clays were deposited in standing water, but the coarser materials have the appearance of marginal moraines laid down while the ice was in retreat. Some of the deposits consist of ill-sorted materials which were melted out of the glacier and others are water-washed and

stratified through stream action. The latter provide building sands that have been used in the towns of the middle Hudson valley. In most banks the sands have a composite character, admixtures, of quartz, feldspar, shale etc., such as are found in glacial detritus. They do not rank generally as high-grade material for engineering work, but by washing and sizing they may be made serviceable for most purposes. Extensive banks are found at Marlboro, Kingston, Albany, Rensselaer, Troy and Mechanicville. Washers are installed at the larger plants, and both sand and gravel are obtained. The Albany-Rensselaer banks are part of a morainal accumulation that stretches across the valley, consisting of gravelly till and imperfectly sorted sands, boulders and gravel. Almost every kind of rock material common to the region north as far as the central Adirondacks occurs in the banks.

In the interior of the State building sands are found under widely varying conditions. At Syracuse the supplies are mainly derived from a series of terraced beds that extend along the range of hills south of the city and are connected with the high-water stages of the Ontario basin in late Pleistocene. A deep valley lies under the city which has been filled by gravels and sands that are also a source of supply.

The Rochester banks are mainly in the Pinnacle hills which lie to the south and southeast of the city and are probably kames. Some sand is obtained from Scottsville where are old delta deposits which afford graded materials.

Buffalo is supplied from the Lake Erie beaches and from scattered banks in the environs opened in glacial beds. The largest source is Point Abino on the Canadian shore of Lake Erie. At Gowanda in the southern part of Erie county are delta deposits which afford a good mortar sand.

In the Black River valley there are terraced delta beds that are extensively worked at Boonville and Forestport and that supply mortar and concrete sands of excellent quality. Utica obtains its building sand mainly from this source. Similar terraced beds which were deposited in former lakes are found in many parts of the Adirondacks.

Some of the best sands in the State are procured from the shores of Oneida lake and from the terraced plains which lie to the west of Rome which are related to the old Lake Iroquois outlet into the Mohawk. They represent glacially accumulated sands which have been thoroughly washed and sorted, and are the cleanest quartz sands to be found anywhere in the interior of the State.

The banks yield products of fine to medium grain, with little of coarser character, that contain above 90 per cent quartz. By washing, the silica content may be raised to 98 per cent or a little more. Besides building sand the deposits yield fire, core, engine, abrasive and glass sand. The principal banks are at Humaston, McConnellsville, Rome, Fish Creek and Cleveland.

Molding sand. The principal deposits of molding sand occur in the Hudson valley in the stretch of 100 miles from Glens Falls south to Kingston. They are part of the terraced deposits that are prominently developed along the river and that extend from 1 to 15 miles back from the present channel. The molding sands lie directly under the soil and are succeeded in depth by deposits of loose, open sand and then by the brick clays, all of which were accumulated in the closing stages of the Pleistocene when the valley was occupied by the flood waters of Lake Albany.

The molding sands represent a phase of the general sand accumulation that at one time must have spread over the whole valley. Since their deposition they have been subjected to erosional agencies of wind and water so that now they have a somewhat patchy distribution. In places they have been heaped up in dunes which are still shifting about, but mostly they are anchored by soil and vegetation so as to form a more or less even mantle over the clay 10 or 15 feet thick as an average. Through wind action the sands have accumulated in places within the inner gorge of the river, but as a rule they occur on top of the terraces at altitudes of from 150 to 400 feet above tidewater.

The sand consists of quartz particles bonded by plastic clay. When uncovered in the bank it appears as a firm, coherent mass which holds up in vertical sections much like the underlying plastic clays. It packs readily in the hand and retains the impression; whereas the open sand associated with it has little or no bonding qualities. In the usual run of commercial sand the clayey matter represents from one-third to one-fourth of the entire mass. This statement applies to the finer sizes — the characteristic and more important products of the district; the coarser sizes as a rule contain less bond.

The sand particles are characterized by a degree of angularity which is seldom observed in deposits by stream or beach action. This results from the crushing down of the quartz under tremendous pressure, whereby the conchoidal fracture surface peculiar to that mineral are developed; the common outlines are triangular or crescentic with little rounding of the edges and points of the grains.

Such sands only result from attrition accompanying the transport of rock debris by moving ice. This angularity has its practical significance in the greater pore space of the sands as compared with those made up of well rounded particles, for in casting metals the gases given off must have opportunity of escape through the mold.

The molding sands proper represent the uppermost layer which is never more than a few feet thick and seldom exceeds 2 or 3 feet. Thus their removal consists in skimming off a thin horizontal seam, rather than working a bank as in the usual building sand operations. The land under exploitation is divided off into sections according to the various qualities of sand present, and then the sod is stripped off down to the layer. This operation is usually performed in successive trenches, each about 3 feet wide, so that the sod and soil of one bench is placed in the trench left by the removal of the sand from the preceding one. The width is determined by the convenience of the workers who carry out the whole operation with hand shovels. After a plot has been worked in this way the land may be returned to agriculture without much deterioration of value. The right of digging the land is usually sold under a contract, the shipper paying a lump sum or a certain amount for each ton removed. The yield obtainable is figured roundly at 1000 tons to the acre for each 6 inches of thickness; an 18-inch seam which is not far from the average size thus will yield 3000 tons for every acre of surface.

The grading of the sand is performed by mere rule-of-thumb tests dependent for their value upon the skill and experience of the operator. The lack of positive standards for sizing and indicating the particular uses of different sands in the field is a feature of present practice that seems to offer opportunity for improvement, since anything like uniformity in grading between different producers is out of the question. To the foundrymen it is a matter of most importance that there should be a fair degree of uniformity in the sands with regard both to the size of the particles and the bonding qualities.

The grades of sand shipped from the Hudson valley run from No. 0, the finest, to No. 4, which is the coarsest size that is commonly produced in the district. No. 0 is the size used in stove-plate and fine castings and consists of sand of which 95 to 98 per cent will pass the 100-mesh screen or of which the average grain diameter is smaller than .147 mm (.0058 inch). No. 0 and No. 1 are the sizes for which the chief demand exists since they are not common in the molding sand districts elsewhere.

Glass sand. Small quantities of glass sand are shipped occasionally from the beds in the vicinity of Oneida lake. At one time these were the support of an active local window glass industry and large shipments also were made to factories at Rochester, Lockport, Ithaca, Black Rock, Syracuse and Clyde. Competition with manufacturing centers in the coal and natural gas fields of Pennsylvania, Ohio and other states caused the decline of the New York industry. The deposits around Oneida lake are of blanket type, and vary from 6 inches to 3 feet in thickness. They are stripped of the soil cover and the sand removed in benches which is prepared by screening to remove the vegetable and other foreign matter and by washing in troughs. The prepared sand contains 97 to 98.5 per cent silica, about .2 per cent ferric oxide and a little alumina, magnesia and lime.

A better grade of glass sand, used for various wares, has been obtained from the Shawangunk grit in the vicinity of Ellenville. Some layers of the grit are practically pure quartz and by crushing yield a superior material that was employed extensively in the works at Corning.

Fire and core sands. These are high silica sands which are obtained in New York State in the Oneida lake region and on Long island. Fire sands are used in the lining of furnaces, for iron and steel manufacture and core sands in the making of cores for iron molding. The important qualities are resistance to corrosion by molten metal and gases and uniformity of grain.

Filter sand. The employment of sand in filtration plants for water purification affords basis for one of the growing branches of the industry. For this use standard specifications in regard to grain diameter, porosity and composition are recognized. The more important qualities are that the sand be clean, free of clay and lime, and possess a degree of porosity that will admit the passage of water readily but retains the mechanical and organic impurities. A high quartz material is the most effective. The deposits on Long island are sources of supply.

Abrasive sand. Minor quantities of sand are required by stone dressing plants in sawing and rubbing of marble and other stones. A pure quartz sand with minimum variation of size and a stout rather than angular grain is called for.

Production of sand and gravel

MATERIAL	1916		1917		1918	
	SHORT TONS	VALUE	SHORT TONS	VALUE	SHORT TONS	VALUE
Building sand.....	4,331 603	\$941 884	3,836 257	\$975 512	1,997 091	\$581 835
Molding sand.....	661 673	570 898	650 427	808 530	519 681	770 512
Fire or furnace sand.....	38 144	16 430	4 540	4 210	a	a
Other sand.....	337 767	134 638	209 227	103 136	261 189	148 844
Gravel.....	2 728 910	980 979	2 418 562	1 155 039	1 394 772	675 281
Total.....	8 098 097	\$2 644 829	7 119 013	\$3 046 447	4 172 733	\$2 176 472

a Included under other sand.

References

- Emmons, Ebenezer. Geology of New York. Report on the Second District 1842
- Hall, James. Geology of New York. Report on the Fourth District, 1843
- Mather, W. W. Geology of New York. Report on the First District, 1843
- Newland, D. H. Albany Molding Sand. Trans. Amer. Foundrymen's Assoc., v. 24, 1916. Also, N. Y. State Mus. Bul. 187, 1916
- Sarie, Clifton J. Economic Geology of Monroe County and Contiguous Territory. N. Y. State Geol. 22d Ann. Rep't, 1904
- Vanuxem, Lardner. Geology of New York. Report on the Third District. 1842

SLATE

The principal slate quarries are in Washington county near the Vermont border. The district is really an extension of the more important Vermont area, as there is no natural boundary between the two and the same beds may be worked on both sides of the line. The productive district includes parts of the towns of Salem, Hebron, Granville, Hampton and Whitehall and in general extends from the Battin kill on the south to the northern limits of Washington county. The extreme length north and south is approximately 25 miles; the width varies from 6 miles in the north to 12 miles at the south end.

Geology. The area is one of extreme complexity in its geological structure. Besides the slates there are present shales, limestones, quartzites and sandstones, all of which have been involved in mountain folding and to a varying extent metamorphosed. The work of T. Nelson Dale has provided most of the information available on the geological structure and general features of the slate district (see appended list of references).

The formations fall into two main groups — Lower Cambrian and Ordovician. In the former belong sandstones, calcareous rocks,

shales and slates, that outcrop in long north-south belts. The workable slates are mostly found in the upper part of the group and near the overlying Ordovician strata, although folding may cause them to appear in the middle part of the belts. These Cambrian slates are mainly developed on the Vermont side and yield such varieties as sea green, unfading green, purple and some variegated slates. They are to be seen also in a series of quarries that extends northward from North Granville, N. Y.

The Ordovician strata include grits and red, green and black slates and shales. They lie in parallel belts with the older series, with which they are interfolded. Red slates are the characteristic product of this group, and they are rather irregular in their distribution and of uncertain continuity, running into shales or green slate of inferior quality.

The field relations of the slates are complicated by the intricate folding and by deep erosion which has removed much of the overlying Ordovician strata. According to Dale they were subjected to two periods of compression and folding, the first coming at the close of the Ordovician and effecting the cleavage foliation and development of grain in the clayey sediments, as well as new mineral combinations, particularly muscovite and chlorite. In the coarser sediments, like sandstone, quartz was deposited as cement and in veins. In the later period of compression slip cleavage was induced on the slaty cleavage, and minor faults, shear zones and diagonal joints were produced. New infiltrations of silica and carbonates took place in the openings made at this time, and along some of the fractures came intrusions of igneous material which consolidated as dikes. Erosion by atmospheric agencies or by ice has been operative since the late Paleozoic and has carved the present surface out of the folded strata.

The cleavage is a variable quality that conditions largely the success or failure of a quarry. Abrupt changes in the cleavability of the material are not infrequent and the cause of much waste in quarrying. As a rule the planes of cleavage are inclined at fairly high angles, usually in excess of 45° . They are seldom or never coincident with the bedding where this can be distinguished, which it often can be by the variations of texture or color or by fossil imprints.

Varieties of slate. The best known product of the New York quarries is the red slate that is practically restricted to Washington county. Its color, a hematite red, and its somewhat silky lustre are characteristic. It finds a ready market for roofing material at fancy prices, for the supply is limited and the quarrying of it an

uncertain industry. The color is the result of an unusually large proportion of ferric oxide or hematite which forms the matrix for the more coarsely granular quartz, mica, carbonates and other components. It is nearly free of metallic sulphides and as nearly permanent under atmospheric conditions as any known slate. It has been employed to some extent for floor tiling and mill stock.

The unfading green is also valued for roofing and shows only a slight change on exposure to the weather. It has a pale greenish gray color, which is lent by a chloritic mineral. In contrast with it is the sea-green slate which changes after two or three years' exposure to brown or brownish yellow hues, through the oxidation of contained ferrous carbonate. Purple slate has a dark purplish brown color and carries considerable hematite, though less than the red. Variegated slate has a pattern of purple and green in irregular mixture. It is largely employed for mill stock and marbleizing. Black slate is present in a few quarries in Washington county; its color seems to be produced by carbonaceous matter.

Quarry localities. The most active quarry section of recent years includes a strip just west of the state line and extending some 15 miles north and south, with Granville near the center. On the north end are the Hampton quarries of purple, green and red slates, including some large openings. The Jamesville quarries, about 2 miles farther south, produce purple, green and variegated slates. Next comes Raceville, with quarries of red and green slates, the principal openings being to the north and west of the hamlet. Middle Granville, $2\frac{1}{2}$ miles south by west of Raceville, has been an important source of purple, green and variegated slate for roofing and mill stock. Granville lies in the red slate, of which there are quarries just north of the town. The same belt extends south from Granville along the state line and through West Pawlet. Slateville, $2\frac{1}{2}$ miles southwest of the latter town, marks about the southern limits of the red slate. Another quarry section lies to the west of the northern part of the first and includes the Hatch Hill quarries in the town of Whitehall and several openings farther south in the town of Granville. It produces red and green slates.

Quarries, most of which no longer operative, are scattered through the eastern townships of Washington county as far south as the Hoosick river. The villages of Hebron, Salem and Shushan have been centers of considerable productive activity in years past. In the southern section the slate belongs mainly to the purple, green and variegated varieties found in the Cambrian strata.

Slate is also found within the western Taconic region, at Hoosick, Rensselaer county. Quarries of black slate were once worked quite

extensively in Rensselaer and Columbia counties. According to Mather in his Report on the First District, "A range of roofing slate extends from New Lebanon through Canaan, Austerlitz, Hillsdale, Copake, Ancram and Pulver's Corners in Northeast. It is believed to be the same as that in which the Hoosick quarries are located. Quarries of roof slate have been opened in this range of rocks in many places. The most important are those in New Lebanon, about $1\frac{1}{2}$ miles from the springs on the east face of the mountain." Near New Hamburg, Dutchess county, occur slate beds that yielded mill stock and were worked as late as 1898.

Quarry work. Open quarry excavation is the only method pursued in the New York State region. The excavation follows the seam or "vein" which usually has a steep dip and the quarries soon become deep pits which require more or less constant pumping to keep them dry. Considerable stripping is often necessary to reach the valuable slate. The blocks as they are loosened by the workmen, who avoid the use of powder as much as possible, are hoisted by a derrick or in the large quarries by a stationary cable with a traveler. Those unfit for use are dumped on the waste piles which are conspicuous objects in the vicinity of all the larger and older quarries. The good slate is loaded on cars or is carried by the hoisting apparatus directly to the trimming sheds where the blocks are split and squared into roofing slates. The mill stock, which lacks the ready cleavage of roofing slate is not finished at the quarries but sent to mills for the purpose, where it is reduced to shape by saws and planes. The cleaving of roofing slates requires a degree of skill but is performed quickly by chisel and mallet.

The wastage in quarry work is enormous, particularly with the red slate, of which the valuable material may constitute only a small fraction of the total quantity removed from the pits. In no other branch of the quarry industry is so much dead work necessary, or the issue of an enterprise surrounded by so much uncertainty. Quarries that have been opened at considerable expense may have to be abandoned before any appreciable return can be obtained, owing to variations in the quality or to the loss of the seam which could not be anticipated. The business, therefore, is a precarious one.

Until recently very little use was made of the waste from the quarries. Some of the red slate is employed for grinding into paint but the amount so used has had no appreciable effect upon the accumulation of the waste. In the last year or two a demand has developed for crushed slate in the preparation of composite roofing

materials and the quarry dumps are being utilized to a larger extent than before.

Present conditions of industry. The recent record of the slate quarrying industry has been disappointing in view of the enterprise and activity that once prevailed in the district. As indicated by the following table of production for the period 1904-18, there has been a marked decline in the quantity of slate quarried, especially in the last five or six years, and the continuation of the downward trend much longer would mean the extinguishment of the industry. The poor showing seems to be the result of a number of unfavorable conditions—some that have a wide application and others that are peculiar to this particular region. The falling off in the building trades within the last few years naturally has influenced the demand for roofing slate which is the principal variety quarried in Washington county; and this has been felt in all the other districts to a greater or less extent. Lack of capital and adequate equipment has been responsible for some of the failures that have occurred in the district. As one writer has remarked: "But the chief cause of failure appears to be the lack of capital properly to push the work, coupled with clumsy methods of quarrying and sharp competition in the market."

In the last year or two a lively demand has sprung up for crushed slate in the manufacture of prepared roofing materials, and this development has contributed to the revival of slate quarrying.

Production of slate in New York

YEAR	ROOFING SLATE		OTHER KINDS	TOTAL VALUE
	Squares	Value	Value	
1904.....	18 090	\$86 159	\$7 441	\$93 600
1905.....	16 460	94 009	1 000	95 009
1906.....	16 248	57 771	4 150	61 921
1907.....	11 686	53 625	1 175	54 800
1908.....	13 735	111 119	98	111 217
1909.....	21 187	126 170	880	127 050
1910.....	14 107	79 857	3 233	83 090
1911.....	11 273	52 311	.....	52 311
1912.....	9 738	83 222	.....	83 222
1913.....	6 109	53 074	.....	53 074
1914.....	4 998	40 650	.....	40 650
1915.....	5 000	45 000	.....	45 000
1916.....	2 727	21 345	.....	21 345
1917.....	3 069	27 511	27 696	55 207
1918.....	852	11 383	102 175	113 558

References

- Dale, T. Nelson. The Slate Belt of Eastern New York and Western Vermont. U. S. Geol. Surv. 19th Ann. Rep't, pt 3, 1899
- & Others. Slate Deposits and Slate Industry of the United States. U. S. Geol. Surv. Bul. 586, 1914
- Leighton, Henry. Slate. N. Y. State Mus. Bul. 142, 1910. p. 70-74
- Mather, W. W. Geology of New York, Report on First District, 1843
- Nevius, J. N. Roofing Slate Quarries of Washington County, N. Y. State Geol. 19th Ann. Rep't, 1901, p. 137-150
- Smock, John C. Building Stones in New York. N. Y. State Mus. Bul. 10, 1890

STONE

The quarrying of stone and its preparation for the varied requirements of building, engineering construction, etc., hold a prominent place in the industrial activities of the State. For many years the value of the annual product ranked second only to that of clay among mineral materials. No other industry includes so many individual enterprises or is as widely represented in the different sections. The resources are notably abundant and in variety are scarcely excelled by those of any other State; practically every kind of building stone known to the trade occurs in quantity if not actually an object of quarry operations.

From the present commercial standpoint the most important of the quarry stones are the limestones and sandstones which supply material chiefly for engineering work, highway improvement and such purposes that do not entail any considerable amount of elaboration previous to shipment. In general these resources are developed to the full market requirements. On the other hand, in the building, monumental and ornamental branches the local industry has not attained the importance relatively that it deserves by reason of the natural wealth of materials adapted to those uses and the local market needs. Herein, undoubtedly, lies the principal field for future enterprise.

The statistics of production which have been collected from year to year show that the industry in general remains practically stationary; in fact lately it has shown rather a downward trend, falling below the average level of earlier years. This has been due largely to the change that has taken place in the methods of building and engineering construction. The use of cement and terra cotta has displaced cut stone to a considerable extent in building operations, while the increasing favor shown for concrete in municipal improve-

ments has worked to the detriment of the trade in flagstone and curbstone. As a partial counterbalance to these losses, a tremendous development has occurred in the crushed stone business through the requirements of concrete construction and road building; yet altogether the changes in progress mean a positive loss industrially, since they involve the substitution of cheap mechanical operations for the trained skill of manual labor.

Production of stone in New York since 1904

YEAR	GRANITE	LIMESTONE	MARBLE	SANDSTONE	TRAP	TOTAL
1904....	\$221 882	\$2 104 095	\$478 771	\$1 896 697	\$468 496	\$5 169 941
1905....	253 955	2 411 456	774 557	2 043 960	623 219	6 107 147
1906....	255 189	2 963 829	460 915	1 976 829	847 403	6 504 165
1907....	195 900	3 182 447	1 571 936	1 998 417	941 627	7 890 327
1908....	367 564	3 119 835	692 857	1 711 585	723 773	6 615 614
1909....	479 955	3 300 383	380 016	1 839 798	1 061 428	7 061 580
1910....	244 763	3 245 807	341 880	1 451 796	909 006	6 193 252
1911....	148 633	3 174 161	278 041	1 060 106	899 414	5 560 355
1912....	202 096	3 510 445	241 847	1 280 743	483 863	5 718 994
1913....	335 642	3 852 678	252 292	1 321 272	1 001 170	6 763 054
1914....	367 242	3 316 063	230 242	1 056 990	770 600	5 741 137
1915....	422 597	3 177 700	120 447	890 411	550 960	5 162 115
1916....	368 119	3 672 454	268 391	714 558	956 100	5 979 622
1917....	182 515	4 406 729	249 180	760 582	684 550	6 283 556
1918....	191 551	4 832 348	135 756	325 351	621 750	6 106 756

If the output of stone is distributed according to use it will be found that more than 50 per cent of the product in value is represented by crushed stone. Limestone and trap are the principal varieties employed for crushing. About 10 per cent of the value consists of building stone, with sandstone, marble and granite as the principal kinds. Curbstone and flagstone account for somewhat less than 10 per cent of the value, and are restricted practically to sandstone which lends itself most readily to such employment. Among other applications that call for appreciable quantities may be mentioned lime and furnace flux, for which limestone is the main representative; paving blocks (sandstone and granite); monumental stone (marble and granite); and rubble and riprap (various).

Production of stone according to use in 1915

KIND	BUILD- ING STONE	MONU- MENTAL	CURBING AND FLAG- GING	CRUSHED STONE	ALL OTHER	TOTAL VALUE
Granite.....	\$261 091	\$19 926	\$1 165	\$61 965	\$78 450	\$422 597
Limestone.....	63 121	.....	1 627	2 072 852	1 040 100	3 177 700
Marble.....	61 600	37 074	.....	.....	21 772	120 447
Sandstone.....	198 743	.....	317 986	77 368	296 314	890 411
Trap.....	.....	.....	.....	497 660	53 300	550 960
Total.....	\$584 556	\$57 000	\$320 778	\$2 709 845	\$1 489 936	\$5 162 115

Production of stone according to use in 1916

KIND	BUILD- ING STONE	MONU- MENTAL	CURBING AND FLAG- GING	CRUSHED STONE	ALL OTHER	TOTAL VALUE
Granite.....	\$173 431	\$9 293	.....	\$55 196	\$130 199	\$368 119
Limestone.....	59 492	a	\$1 621	2 085 748	1 525 593	3 672 454
Marble.....	133 238	75 587	.....	.....	59 566	268 391
Sandstone.....	184 971	.....	259 047	124 555	145 985	714 558
Trap.....	4 000	.....	.....	952 100	.....	956 100
Total.....	\$555 132	\$84 880	\$260 668	\$3 217 599	\$1 861 243	\$5 979 622

a Included under "all other."

Production of stone according to use in 1917

KIND	BUILD- ING STONE	MONU- MENTAL	CURBING AND FLAG- GING	CRUSHED STONE	ALL OTHER	TOTAL VALUE
Granite.....	\$31 586	\$5 733	a	\$30 025	\$115 171	\$182 515
Limestone.....	40 155	.....	.....	2 281 236	2 085 338	4 406 729
Marble.....	133 906	79 076	.....	.....	36 198	249 180
Sandstone.....	140 555	.....	\$322 037	109 270	188 720	760 582
Trap.....	.....	.....	.....	672 450	12 100	684 550
Total.....	\$346 202	\$84 809	\$322 037	\$3 092 981	\$2 437 527	\$6 283 556

a Included under "all other."

Production of stone according to use in 1918

KIND	BUILD- ING STONE	MONU- MENTAL	CURBING AND FLAG- GING	CRUSHED STONE	ALL OTHER	TOTAL VALUE
Granite.....	\$15 016	\$8 311	.....	\$60 260	\$107 964	\$191 551
Limestone.....	.....	.....	.....	2 621 527	2 210 821	4 832 348
Marble.....	52 085	43 953	.....	^a	39 718	135 756
Sandstone.....	60 942	.....	\$157 064	2 286	105 059	325 351
Trap.....	.....	.....	.....	621 750	.....	621 750
Total.....	\$128 043	\$52 264	\$157 064	\$3 305 823	\$2 463 562	\$6 106 756

^a Included under "all other."

GRANITE

Granite is both a specific and a general term. When used in the restricted scientific sense it means an igneous rock of thoroughly crystalline character in which the chief constituents are feldspar, quartz and mica. Such a rock has a massive appearance; that is, the constituents are uniformly distributed in every direction, and owing to the predominance of the feldspar and quartz the color is rather light, commonly gray or pink. As a variation to the uniform distribution of the minerals, the latter may develop a plane parallel arrangement through the influence of compression when the mass was still deeply buried in the earth's crust. A granite with this parallel or foliated texture is known as a granite gneiss.

The commercial definition of granite is much broader than that given and includes almost any of the crystalline silicate rocks (usually igneous) that possess the requisite physical qualities for use as architectural or monumental stone. In most cases the commercial product is actually a granite in the true sense, but not infrequently it may be a syenite which lacks quartz, or a diorite consisting of plagioclase feldspar and hornblende, or anorthosite which contains little else than basic plagioclase feldspar. So-called black granites are mainly gabbros and diabases with a large proportion of the iron compounds pyroxene, hornblende and magnetite.

The broader usage will be followed in the present classification, as all the above-named rocks are quarried in this State.

The only silicate rock not included under granite is diabase or trap which by reason of the special features surrounding its production and uses is classed by itself.

Distribution. Granites and the related igneous rocks are restricted in outcrop to two well-defined areas in New York — the Adirondack region in the north and the Highlands in the southeast. Outside of these regions they occur only in stray boulders or as part of the general morainal accumulation left by the ice invasion which spread over most of the State. The granitic rocks in their economic bearings have been described quite fully in Bulletin 181 of the State Museum. Only a brief resumé of their character and distribution will be given in this place.

The great expanse of crystalline rocks comprised within the Adirondacks affords a variety of quarry materials. The commoner types which are useful for building or monumental stone include granite proper, syenite and anorthosite. These are found in both massive and gneissoid development. Gabbros occur locally and have limited application for purposes of road improvement and engineering construction for which they take the place of trap. The red granite of Grindstone, Picton and Wellesley islands in the St Lawrence river is one of the characteristic products of the region, widely known as excellent building and monumental stone. In its usual phase it is a bright red, medium to coarsely textured granite of which the predominant mineral is feldspar associated with milky quartz and biotite. Most of the product in earlier years came from Grindstone island which furnished large quantities of structural and monumental stone to the cities on the St Lawrence and Great Lakes. Paving blocks were also made in quantity. Most of these quarries are now idle or worked only in a small way. In recent years the principal operations have been carried on by the Picton Island Red Granite Company whose property is situated on the northern end of Picton island, by the Wisconsin Granite Company which has operated quarries on Wellesley island and at Alexandria Bay and by J. Leopold & Company with quarries at Alexandria Bay. The stone in the vicinity of Alexandria Bay differs from that above described in having a fine texture and color that ranges from pale pink to nearly white. It is not much used for structural purposes, but affords a good material for paving blocks and crushed stone. Small quantities of monumental and structural granite have been obtained from Parishville in eastern St Lawrence county. The stone has a dark red, fine grained body with curved and branching veinlets of bright red color, that are of somewhat coarser grain, but of the same mineral composition as the body. It is known in the trade as St Regis Red veined granite. An enormous body of coarse red granite of attractive appearance and sound quality,

though not yet utilized to any extent, is found in the southern part of St Lawrence county in the towns of Fine and Pitcairn along the line of the Carthage and Adirondack Railroad. There are many available quarry sites along the railroad. On the west the granite is bordered by a dark close-textured syenite not adapted for building purposes, but suited for crushed stone and engineering work requiring a strong material.

In the eastern Adirondacks the available quarry materials suitable for architectural and monumental work consist of granite, syenite and anorthosite. These formations are of widespread occurrence although it is rarely that they possess the qualities requisite for crushed stone as they have been largely metamorphosed into gneisses. One of the localities where massive phases of these rocks are obtainable is in the vicinity of Ausable Forks. For several years past a considerable amount of monumental stone has been shipped from this section principally consisting of green syenite. Quarry sites are found along both sides of the Ausable river above and below the village of Ausable Forks. The monumental syenite has a bright green color on polished surfaces, takes a lustrous polish and brings out in strong relief the finest tracery. It is an exceptionally strong and durable stone, but some qualities show a tendency to bleach or turn yellow on long exposure. The product from this locality has been marketed under the names of Adirondack green granite and Killarney green granite. Anorthosite outcrops to the south of the village along the east branch of the Ausable. It consists of a fine ground mass of feldspar of greyish color set off by inclusions of black pyroxene and hornblende lending the appearance of a medium grey granite. The stone is well adapted for building purposes. Other quarries of anorthosite are found in the vicinity of Keeseville and south of there near Augur lake. A considerable quantity of stone was once taken from the Keeseville quarries of which examples are to be seen in Keeseville itself and in one or two of the public buildings in New York City. The Empire State Granite Company has been engaged in recent years in the development of quarries southeast of Keeseville where is found a light green variety of the stone which is very attractive both in rock finish and polished work. The exposures here and also on the shores of Augur lake take the form of great ledges in which the rock is broken at regular intervals by joints so that it can be readily quarried. The stone possesses a well marked rift and grain similar to that of ordinary granite which facilitates its cutting. In the vicinity of Dannemora, Clinton county, a pink or grey granite of

somewhat gneissic appearance is exposed and has been quarried to some extent. Its architectural use is well illustrated in the buildings of the state hospital and prison at Dannemora. The Dannemora Granite Company has worked the quarries occasionally in recent years as demand warranted operations. In the town of Wilton, Saratoga county, about 2 miles north of Saratoga Springs, a grey granite outcrops on the ridge to the west of the valley. The stone has a fine granular texture with occasional knots or segregations of pegmatite. It has been employed principally for paving blocks, but some examples of its use as building stone are to be found in Saratoga Springs. A handsome porphyritic granite with pink feldspar in a ground mass of dark grey color occurs at Horicon, Warren county, near the outlet of Brant lake. At White Lake, Oneida county, is found a pink, fine-grained granite that has been quarried to a limited extent and near Gloversville, Fulton county, occurs a dark grey biotite gneiss which has been employed for architectural and general building purposes.

A variety of granitic materials is found in the Highlands region of southeastern New York in Orange, Putnam and Westchester counties. Perhaps the best known of the granites for building work is the Mohegan granite which occurs in a large boss 5 miles east of Peekskill. Two colored varieties of the granite occur, one a light grey or pink in hue and the other a rich yellow or yellowish brown. The latter has scarcely a rival in beauty and uniformity of color among eastern granites and its warm subdued effect in buildings has won favor wherever the stone has been introduced. It has been employed in many large structures in New York City. The Mohegan Granite Company has been the largest producer of this grade. The grey granite is represented in the new Croton dam and in some of the buildings in the towns along the Hudson river. In southern Westchester county occurs a light-colored gneissic granite which has been commonly called the Yonkers gneiss and belongs to one of the earlier Precambrian intrusions in the Highlands region. It is quite free of knots and streaks, but almost invariably shows a parallel structure in the arrangement of the mica. It occurs in several areas of which the principal one forms a belt that parallels the Bronx river, and Harlem Railroad from a point just south of Mount Vernon to Hartsdale and White Plains. A second area of considerable extent lies along the axis of the main belt, but farther north near Valhalla. In the latter area are situated the quarries that have supplied the stone for the immense Kensico reservoir dam, which is remarkable for its architectural features as well as

for its size. In the former area are included quarries near Dunwoodie which have supplied stone for many structures in Yonkers and vicinity, at Hartsdale, Scarsdale and near Tarrytown.

Granite is exposed over an area of many square miles at the northern portals of the Hudson gorge composing the ridges known as Storm King and Breakneck mountains. It has usually a foliated appearance, but in the quarry shows a massive structure and is undoubtedly of igneous derivation. It contains frequent streaks and knots so that it is not well adapted for architectural purposes, but is serviceable for foundation stone and for crushing purposes. Quarries were formerly operated at the base of Storm King and Breakneck mountains, but have been inoperative for several years. A local intrusion of massive grey granite occurs between Manitou and Garrison in Putnam county about one-fourth of a mile back from the river. It has a fine grained and medium grey well-blended color. The principal opening is known as King's quarry operated at one time by the King Granite Company. The rock is illustrated in some of the large structures in New York City and some of the buildings of West Point. Outcrops of a dark gray granodiorite in the towns of Mamaroneck, Rye and Harrison, Westchester county, have yielded considerable quantities of stone for building and, engineering work. It is a markedly gneissic rock consisting of white feldspar with smoky quartz and large amounts of black mica arranged in parallel bands. It has a rather sombre effect when seen in buildings. The former quarry sites have mostly been abandoned and built over, but the quarry of Faillace Brothers at Mamaroneck has been worked up to the last few years. Large quantities of stone for building and foundation work have been obtained from various localities in the Fordham gneiss area, which spreads over an extensive part of Westchester county. It is a banded light and dark material of extremely variable composition and appearance. The banding is due in part to injection by granite. Quarry sites are to be found at Uniontown, Bryn Mawr, Lowerre and Fordham.

On the west side of the Hudson river in Orange county granitic rocks are sufficiently widespread to afford many quarry sites, but the most important exposures, so far as building stone is concerned, are in the southwestern part of the county near the New Jersey state line. Pochuck mountain which lies partly in New York and partly in New Jersey is made up in part of a coarse massive to slightly foliated hornblende granite serviceable both for building stone and for general engineering work. The Empire State Granite

Company once operated quarries in the area from which stone was obtained for buildings in Paterson, N. J. Farther north are the large bosses of granite known as Mt Adam and Mt Eve. The stone resembles that from Pochuck mountain in general composition and appearance, being a hornblende granite with subsidiary mica and having a coarse texture and greyish color. Old quarries exist on the north slope of Mt Adam and the western slope of Mt Eve. They were opened about 1889 or 1890. Those on Mt Eve supplied considerable dimension stone for building operations in the northern towns in New Jersey. Gneissic granites are found along the Erie Railroad between Suffern and Ramapo, Rockland county.

LIMESTONE

Here are included the carbonate rocks — limestones and dolomites — of the granular nonmetamorphic sorts that have no particular value for ornamental stone. Crystalline limestones that lack this quality are also considered under this head, as well as the waste product of marble quarries which finds use as crushed stone, flux and for other purposes.

New York State has a varied assortment of limestones of which there are individual representatives in most of the important geologic groups. Consequently they are widely distributed over the State. Practically the only large areas not well supplied with these rocks are the southern section on the Pennsylvania border and the central Adirondacks; the Upper Devonian strata of shales and sandstones, with no considerable limestone beds, extend in a broad belt west from the Catskills through the southern tier of counties to Lake Erie, while in the interior of the Adirondacks the formations are largely silicate rocks — gneisses, granites, anorthosite etc.

Geologically the limestones range from early Precambrian to late Devonian age. The oldest are represented by the Grenville limestones of the Adirondacks and the Highlands which are thoroughly crystalline and occur in patches of strongly upturned and folded strata. A later member of the Precambrian probably is the Inwood limestone of Westchester county, also metamorphosed and folded. It is these members that afford the marbles used for building, ornamental and monumental work. Among the later formations, limestones are prominent in the upper Cambrian, Ordovician, Silurian and the lower portion of the Devonian systems. Here, as a rule, they lie in regularly stratified beds, horizontal or but slightly dis-

turbed, and have a fine granular or occasionally microcrystalline texture. Their outcrops can often be traced for long distances.

The present discussions of the resources of limestone will be restricted to an outline of the characters and distribution of those representatives that have chief importance from an economic standpoint.

Crystalline (mainly Precambrian) limestones. The Grenville formation of the early Precambrian includes limestones among its members, always metamorphosed and often surcharged with secondary silicates. Some occurrences, however, show a high content of carbonates, ranking with the best of the nonmetamorphic limestones, so that they deserve consideration in this place. They appear in belts and isolated patches and are very unequally distributed within the Adirondack Precambrian region. The principal development is in St Lawrence and Jefferson counties, where there are four considerable belts, besides numerous small exposures. The argest area is the belt that stretches from Canton, St Lawrence county, to near Antwerp village, Jefferson county, with a width of from 1 to 7 or 8 miles and a surface of 175 square miles. A parallel belt occurs a few miles northwest, about midway between the first and the St Lawrence river, in the towns of Macomb, Hammond and Rossie, St Lawrence county. Southwest of the main area is the Edwards-Fowler belt, affording a very impure limestone in most outcrops but occasionally fairly high in carbonates. The fourth belt lies farther southeast across the St Lawrence-Lewis county boundary, and is well exposed near Harrisville, Bonaparte Lake and Natural Bridge. In the interior of the Adirondacks the limestones are rarely represented, although they are found in some of the valleys in Essex county 30 or 40 miles from the border, as around Newcomb and Minerva, and with increasing frequency towards the Champlain valley. On the north and south sides of the Adirondacks they are sparsely developed.

The Grenville limestones are quarried for marble around Gouverneur. Crushed stone, flux and lime are also made in this section. The principal lime-burning operations have been carried on near Richville and Natural Bridge; at the latter place the product is magnesian lime, used for refractories and paper making. The chemical character of the Grenville limestones is exhibited by the following analyses:

Analyses of crystalline limestones of the Adirondacks

	1	2	3	4	5	6	7
Insol.....	3.55	1.26	1.01	.....	.....	.....	.....
SiO ₂.....	.....	.....	.....	.28	1.64	.5	1.12
Al ₂ O ₃	.13	.65	.23	} .10	{ .04	} 1.3	1.89
Fe ₂ O ₃	.08	.29	.63				
MgO.....	.....	.....	.....	20.64	.....	.....	.....
MgCO ₃	6.40	7.50	6.85	.....	21.79	9.63	19.97
CaO.....	.....	.....	.....	31.45	.....	.....	.....
CaCO ₃	87.06	87.47	88.94	.....	76.17	88.67	76.48
H ₂ O.....	1.68	1.46	1.74	.....	.....	.....	.....
CO ₂.....	.....	.....	.....	47.38	.....	.....	.....
S.....	.05	.02	.04	.06	.....	.....	.....

1 Gouverneur; St Lawrence Marble Co., Extra Dark quarry. R. W. Jones, analyst.

2 Gouverneur; Gouverneur Marble Co. R. W. Jones, analyst.

3 Gouverneur; Rylestone quarry. R. W. Jones, analyst.

4 Gouverneur; White Crystal Marble Co. Watertown Arsenal, analyst.

5 Harrisville; R. W. Jones, analyst.

6 Six miles south of Canton. Professor Priestley, analyst.

7 Canton; Stevens quarry. Professor Priestley, analyst.

The crystalline limestones in southeastern New York include small areas in the Highlands gneiss complex which are perhaps the equivalents of the Adirondack Grenville limestones. They are found along Sprout Brook valley, north of Peekskill, as a narrow belt 5 or 6 miles long; near Garrison and Cold Spring, Putnam county; and in various parts of Orange county on the west side of the Hudson river. They are magnesian, but do not usually carry enough magnesia to be classed as dolomites. In some places they are fairly free from silicate impurities.

In southern Orange county a white crystalline limestone is developed on a considerable scale, mainly in the towns of Warwick, Minisink and Goshen, as an extension of the New Jersey (Franklin Furnace) limestone belts. It occupies the valley that borders the Precambrian gneiss ridges in the town of Warwick and may be seen in outcrop near Warwick village and more especially about New Milford, where it underlies a series of low hills and is in many places thinly soiled. Although not quarried to any extent in New York State there are very extensive operations just across the line in New Jersey. Another belt of the limestone outcrops around Pine Island and probably underlies much of the low marshy tract known as the Drowned Lands of the Walkill. Quarries have been opened just southeast of Pine Island. The limestone is a medium to coarse

grained crystalline white limestone, with usually small amounts of impurities. The magnesia content is variable, ordinarily only 2 to 3 per cent, but may reach the proportions of dolomite. The following analyses show the character of the material.

Analyses of crystalline limestones of southern Orange county

	1	2	3	4	5
SiO ₂	.31	.48	1.60	2.47	1.25
Al ₂ O ₃	.26	1.62	.85	.96	.57
Fe ₂ O ₃					
MgO.....	2.87	1.90	2.52	3.74	2.96
CaO.....	51.56	51.37	51.10	48.45	50.08
CO ₂	43.67	42.39	42.91	42.80	42.52
P.....	.006	.005	.005	.005	.008
S.....	.013	.020	.010	.028	.015

1, 2, 3, 4. New Milford, Orange Co. (George E. Winter's farm). Analyst Bethlehem Steel Co.'s laboratories.

5 New Milford, Orange Co. Analyst, Bethlehem Steel Co.'s laboratories.

The main development of the limestones on the east side of the Hudson river is along the Harlem Railroad in Westchester, Putnam and Dutchess counties. In Westchester county the Inwood limestone, a white dolomite, has been the source of large quantities of structural stone, furnace flux, lime and crushed stone. Farther north in Dutchess county is a belt of white to bluish gray dolomite, worked for marble and lime. Quarries for flux, lime and structural stone have been worked also at Ossining.

Analyses of crystalline limestone of southeastern New York

	1	2	3	4	5	6	7
SiO.....	.70	.90	2.08	2.31	.24	2.05	.70
Al ₂ O ₃				.40	.19	1.11	.37
Fe ₂ O ₃	1.35	1.38	.56	.25	.21	.99	.25
MgO.....					21.25	15.37	20.25
MgCO ₃	6.00	10.00	37.79	36.80			
CaO.....					30.16	34.63	30.63
CaCO ₃	91.40	86.60	58.72	59.84			
CO ₂	n. d.	n. d.	n. d.	n. d.	47.3	44.11	46.66

1 Sprout brook valley; Frost quarry. H. D. Gehret, analyst.

2 Sprout brook valley; Couch farm. H. D. Gehret, analyst.

3 White Plains; James O'Connell quarry. Huntington, analyst.

4 Pleasantville; quarry of Snowflake Marble Co. H. Ries, analyst.

5 Tuckahoe; quarry of New York Marble Co. W. F. Hillebrand, analyst.

6 Ossining; Mark's quarry. New Jersey Zinc Co., analyst.

7 Wingdale; quarry of South Dover Marble Co. Analysis supplied by the company.

Upper Cambrian limestones. These are mostly magnesian limestones and dolomites that were earlier classed as Calcareous, but now given independent places in the classification. They include the Hoyt limestone, which is exposed in the vicinity of Saratoga Springs, and the Little Falls dolomite as the main members, both rather impure massively bedded rocks that find use mainly for foundation work or crushed stone. They are dark gray, weathering to buff, with a proportion of lighter grains or rhombs of calcite which give an irregular subcrystalline texture to the materials. The Little Falls dolomite is well shown in the old quarries about Little Falls and east of there at St Johnsville, Canajoharie and Cranesville in the Mohawk valley. The general composition of the rock is indicated by the analyses below of samples from Little Falls (1) and from Amsterdam (2) quoted from Bulletin 44 of the New York State Museum:

Analyses of Cambrian limestones

	1	2
SiO ₂	10.5	7.46
Al ₂ O ₃	3.93	2.48
Fe ₂ O ₃	.77	1.07
MgCO ₃	47.96	18.19
CaCO ₃	36.89	71.76

Ordovician limestones. In the succession of Ordovician strata limestones are represented in force in the Beekmantown, Chazy, Lowville, Black River and Trenton formations. They are distributed over quite an extensive surface, mainly on the eastern, southern and western borders of the Adirondacks.

The Beekmantown limestone, now limited to the middle and upper beds of that series as formerly defined, is developed in the Champlain valley. It occurs on the New York side in detached areas, usually down-faulted blocks that are remnants of a once continuous belt. It is represented in the basal portion of the limestone area that outcrops in Washington, Saratoga and Montgomery counties along the Adirondack margin. In the Champlain valley it has been quarried at Port Henry for furnace flux for local use. Quarries have been worked near Amsterdam, while at Tribes Hill occurs an earlier but quite similar stone, called the Tribes Hill limestone, that has also been worked.

In southeastern New York there are siliceous magnesian limestones which may be representative of the Beekmantown, although their exact position in the stratigraphic series has not been definitely determined. They are especially developed in Orange, Westchester and Rockland counties and are quarried at Tompkins Cove, Verplanck Point and near Newburgh.

The Chazy limestone is exposed in discontinuous patches from Saratoga county north to the Canadian boundary. It attains its maximum thickness in eastern and northeastern Clinton county, and has been quarried around Plattsburg, Chazy, on Willsboro point, Valcour island and other places. It is the earliest representative of the Paleozoic limestones that has a fairly uniform and high calcium content; the analyses show up to 95 per cent or more of calcium carbonate. It has a grayish color and subcrystalline texture. The fossiliferous beds yield attractive polished stone and are quarried near Plattsburg for interior work. It is used for lime, furnace flux and is adapted to portland cement manufacture. On the west side of the Adirondacks, the Pamela limestone, described in the reports¹ by Cushing and Ruedemann on the areal geology of that section, belongs to the Chazy series. It covers a considerable area in Jefferson county between Leraysville and Clayton, and has been rather extensively worked for building stone and lime.

The Lowville, Black River and Trenton formations, of the Mohawkian or Trenton group, are closely related in their features and distribution. They rank among the very important quarry materials of the State. They are represented in the Champlain valley, but are especially prominent on the Vermont side; from the latter area a belt reaches across northern Washington county to Glens Falls in Warren county and is continued into Saratoga county. Quarry openings in this section occur near Plattsburg, Crown Point, Larabees Point, Sandy Hill, Smiths Basin and Glens Falls. Portland cement, lime, building stone and crushed stone are produced in the vicinity of Glens Falls. In the Mohawk valley there is a considerable exposure of the limestones near Amsterdam and north of there across the towns of Perth and Broadalbin, with several quarries that yield building stone, crushed stone and material for lime manufacture. The largest area of these limestones is the belt which begins in the Mohawk valley near Little Falls and extends northwest with gradually increasing width across Oneida, Lewis and Jefferson counties to the St Lawrence river. Within its limits are

¹ See especially, Geology of the Thousand Islands Region, N. Y. State Mus. Bul. 145, 1910.

many quarry sites, such as at Chaumont, Clayton, Cape Vincent and Watertown, Jefferson county; Lowville, Port Leyden and Collinsville, Lewis county; Boonville, Prospect and Trenton Falls, Oneida county; and Middleville, Herkimer county. The limestones vary in composition and physical character according to locality and geologic position. They are predominantly dark gray and some beds nearly black, often highly fossiliferous. As a rule they contain small amounts of magnesia and run as high as 97 or 98 per cent calcium carbonate. The lower part of the group is heavily bedded and well adapted for building stone; the upper beds are thinner and often shaly. Limestones of the Trenton group are exposed in the Hudson valley below Albany, as detached areas within the Hudson River shales. Eckel¹ has called attention to the occurrences in the Poughkeepsie region. Limestones made up of a series of exposures with the same trend, are found near Rochdale, Pleasant Valley and Salt Point, east and northeast of Poughkeepsie. They contain some magnesia, up to the maximum limit admissible for portland cement, and also considerable silica. There are no quarry operations under way at present in the district.

Analyses of Ordovician limestones

	I.	2	3	4	5	6	7	8	9	10	11
SiO ₂	12	10.46	3.42	8.02	9.22	4.42	17.28	.72	2.43	1.38	.72
Al ₂ O ₃	4.13	1.93	1.70	4.08	4.16	2.23	5.21	.39	.41	.58	1.50
Fe ₂ O ₃	1.05	1.8				.16	.92				
MgO.....	16.74	17.65	5.08	2.38	1.70				1.00	.72	.80
MgCO ₃						37.74	18.46	3.02			
CaO.....	26.34	27.75	47.14	46.28	45.24				51.00	55.26	54.28
CaCO ₃						55.87	58.17	96.24			
CO ₂	39.1	40.99							n. d.	n. d.	44.00

	12	13	14	15	16	17	18	19	20	21	22
SiO ₂	.7	3.9	1.1	6.13	1.25	6.7	8.45	2.59	3.96	3.09	6.5
Al ₂ O ₃	1.	1.3	.8	.79	3.	3.03	2.72	1.21	1.7	1.15	1.67
Fe ₂ O ₃	.7		.5	.61		.21	.84	.61		.49	.76
MgO.....	1.4	1.58	.75					1.04			
MgCO ₃				2.45		tr	3.42		3.78	1.63	2.68
CaO.....	53.9	52.15	53.17		52.78			52.			
CaCO ₃				88.49		89.15	84.6		91.27	94.11	88.44
CO ₂	42.5	n. d.	45.08					42.			

1 Ordovician limestone, Tompkins Cove, Rockland county. N. Y. State Museum Bul. 44.

2 Ordovician limestone, Newburgh. Miller quarry. Idem.

3, 4, 5 Trenton group, near Poughkeepsie. U. S. Geol. Survey Bul. 522.

¹ Portland Cement Materials and Industry in the United States. U. S. Geological Sur. Bul. 522, 1913, p. 275-76.

- 6 Beekmantown limestone, Ogdensburg. Howard's quarry, upper part. N. Y. State Museum Bul. 44.
- 7 Beekmantown limestone, Ogdensburg. ar'd's quarry, lower part. Idem.
- 8 Chazy limestone, Chazy. D. H. Newland, analyst. Idem.
- 9 Chazy limestone, Willsboro Point, Essex county. T. G. White, analyst. Idem.
- 10 Trenton group, Smith's Basin, Washington county. Keenan quarry. Idem.
- 11 Trenton group, Smith's Basin, Keenan quarry. H. Ries, analyst. Idem.
- 12 Trenton group, Whitehall. Harris quarry. Idem.
- 13 Trenton group, Glens Falls; upper bed. Idem.
- 14 Trenton group, Glens Falls; lower bed. Idem.
- 15 Trenton group, Amsterdam. Hewitt quarry. Idem.
- 16 Trenton group, Amsterdam. Hewitt quarry; upper layer. Idem.
- 17 Trenton group, Ingham Mills, Herkimer county. Butler quarry. Idem.
- 18 Trenton group, Ingham Mills, Herkimer county. Butler quarry. Idem.
- 19 Trenton group, Prospect, Oneida county. J. D. Irving, analyst. Idem.
- 20 Trenton group, Lowville. J. Watson's quarry. Idem.
- 21 Trenton group, Collinsville. Lewis county. Roberts quarry. D. H. Newland, analyst. Idem.
- 22 Trenton group, Port Leyden. Snyder quarry. D. H. Newland, analyst. Idem.

Silurian limestones. The lowermost formations of the Silurian comprise slates and sandstones without any calcareous beds. In the middle or Niagaran group these rocks become important and are divided among the Clinton, Lockport and Guelph members.

The Clinton limestone appears mainly in the western section of the Clinton belt of strata which outcrops all the way from Otsego county to the Niagara river, on a line a little south of the Mohawk river, across Oneida lake and thence directly west. East of Rochester the limestone occurs in thin, discontinuous, usually shaly layers, intercalated in shales which constitute the main element. To the west of that locality it thickens and in Niagara county greatly predominates over the shale, having a thickness altogether of about 30 feet. The upper 10 or 12 feet of the succession consist of light-colored fossiliferous beds which are fairly pure calcium limestones. The middle and lower parts are more silicious and the middle layer is a dolomite. On account of the scarcity of high calcium limestones in the western part of the State, for which a large demand exists in Buffalo and vicinity, the Clinton beds have considerable economic importance, and large quarries have been opened near Pekin and Gasport, Niagara county. The principle use of the product is for flux in iron blast furnaces.

The Lockport and Guelph are magnesian limestones or dolomites. They are quite similar in general characters but differ in their fossil content. The Lockport is the more persistent formation and outcrops in a belt, some 4 or 5 miles wide, from Niagara Falls to the western border of Onondaga county, whence it can be traced with diminishing

width into Madison county, while the strata are recognizable as far east as Herkimer county. The Guelph, on the other hand, is restricted in outcrop to a limited area in Wayne, Monroe, Orleans and Niagara counties. In the vicinity of Rochester the general succession consists of 62 feet of Lockport dolomite at the base, followed by 3 feet of Guelph dolomite, 32 feet of Lockport and finally 8 to 10 feet of Guelph at the top. The Lockport is rather thin bedded and siliceous at the base, with more or less of bituminous shaly matter; the beds thicken higher up and the topmost ones are fossil dolomite of fairly pure nature. The color is dark gray to light gray for the fossil variety which contains spots or blotches of red and has ornamental qualities when polished. Cavities and veins with crystallized calcite, dolomite and other minerals are not uncommon. Quarries of constructional stone have been worked around Niagara Falls, Lockport and Rochester, and magnesian lime has been made from the Lockport member in Niagara county and from the Guelph near Rochester. Examples of the architectural use of the dolomite are to be seen in Buffalo, Niagara Falls and other cities in the western section of the State.

The Cayuga group in the upper part of the Silurian system includes a number of formations that are important for their limestone beds. The Salina is mainly a shale formation but near the top occur impure calcareous strata which are known as the Bertie water-lime. The Cobleskill, Rondout and Manlius are largely calcareous in character.

The Bertie has its main development in the State within the borders of Erie county, but it reaches into Genesee and Monroe counties and is known as far east as Otsego county. It has been extensively quarried for natural cement in Buffalo, Falkirk and Akron; this industry is now discontinued and the quarries are inoperative. The cement rock consists of a layer 5 to 8 feet thick made up of drab or gray argillaceous limestone enclosed within dark impure beds, of which the so-called "bullhead" stratum, a magnesian limestone, has been used for cut stone. This bed has the stratigraphic position of the Cobleskill formation¹ (Coralline limestone of Hall).

The Rondout and Manlius limestones have supplied large quantities of material for natural cement manufacture. The extensive cement mines in the Kingston district are located in the Rondout, as is also that formerly worked at Howes Cave, Schoharie county.

¹ C. A. Hartnagel, Preliminary Observations on the Cobleskill ("Coralline") Limestone of New York. N. Y. State Mus. Bul. 69, 1903, p. 1109-75.

The formation in the two localities is 40 to 60 feet thick and consists of impure magnesian limestones in rather massive beds of fine texture. The rock has not been employed to any great extent for other purposes. The Manlius limestone is worked for natural cement in Onondaga county, where there are two beds of water-lime measuring about 4 feet thick, in character an argillaceous dolomite, separated by a comparatively pure, blue calcareous limestone of similar thickness. The blue limestone associated with the cement layers has been extensively employed as cut stone in Syracuse and vicinity; it is usually worked in connection with the overlying Onondaga limestone. The quarry localities are mentioned under that formation. In eastern New York the Manlius is exposed along the west side of the Hudson river in Greene and Albany counties, also in Becraft mountain, Columbia county, and in Schoharie county, where it has been a source of building stone, crushed stone and of lime. It is here a fairly pure calcium limestone.

Analyses of Silurian limestones

	1	2	3	4	5	6	7
SiO ₂	.90	10.40	3.40	1.7	7.09	.7	.29
Al ₂ O ₃	.68	5.20	.60	1.30	2.57	.95	.43
Fe ₂ O ₃				.75	.96	.8	.46
MgO.....	.....	.....	.....	17.45	.....	20.05	.....
MgCO ₃	4.95	30.25	1.50	.....	33.42	.....	43.3
CaO.....	.....	.....	.....	32.21	.....	30.5	.....
CaCO ₃	92.99	52.54	93.72	.....	56.19	.....	56.01
CO ₂.....	.....	.....	.....	46.79	.....	45.24	.....

	8	9	10	11	12
SiO ₂	8.	4.02	1.6	5.35	10.97
Al ₂ O ₃.....	.....	1.48	.7	.56	4.46
Fe ₂ O ₃.....	.....	1.07		.61	1.54
MgO.....	.....	.....	.....	.....	16.9
MgCO ₃	30.	35.09	1.11	18.86	.....
CaO.....	.....	.....	.....	.....	27.51
CaCO ₃	51.	57.87	97.	85.41	.....
CO ₂.....	.....	.....	.....	.....	37.94

- 1 Clinton limestone, upper layer, Lockport. U. S. Geol. Surv. Bul. 522
- 2 Clinton limestone, middle layer, Lockport. Idem.
- 3 Clinton limestone, lower layer, Lockport. Idem.
- 4 Lockport dolomite, south of Niagara Falls. William Massing's quarry. H. Ries, analyst, N. Y. State Mus. Bul. 44.
- 5 Lockport dolomite, quarry $1\frac{1}{2}$ miles east of Lockport. D. H. Newland, analyst. Idem.
- 6 Guelph dolomite, Gates, near Rochester. Snow's quarry. D. H. Newland, analyst. Idem.
- 7 Guelph dolomite, Rochester. Copeland quarry. D. H. Newland, analyst. Idem.
- 8 Bertie Waterlime, Buffalo. Quarry of Buffalo Cement Co.
- 9 Bertie Waterlime, near Leroy, Genesee county, Howell farm. D. H. Newland, analyst. Idem.
- 10 Manlius limestone, Split Rock, Onondaga county. Quarry of E. B. Alvord. Idem.
- 11 Manlius limestone, Split Rock, Onondaga county. Quarry of Solvay Process Co. Idem.
- 12 Manlius limestone, cement rock, Jamesville, Onondaga county. Quarry of E. B. Alvord. Idem.

Devonian limestones. The more important calcareous deposits among the Devonian formations are comprised within the Helderbergian group, the Onondaga limestone and the Tully limestone. The higher Devonian strata, represented by the Portage and Chemung formations with the Catskill equivalents of eastern New York, are devoid of limestone beds of workable size and character; the Tully occupies the most southerly position of all the commercial limestones in the area west of the Catskill mountains.

The Helderbergian group is made up of several distinct stratigraphic units or formations inclusive of the Coeymans, Kalkberg, New Scotland and Becraft, all of which are essentially calcareous in nature. They are restricted in area to the eastern part of the State, the Coeymans alone extending as far as Onondaga county to the vicinity of Manlius. The outcrop east of Oneida county lies along the highland south of the Mohawk river, which becomes the Helderberg mountains in Albany county, where the limestones have a thickness of 200 feet. Here the outcrop swings around to the south, parallel with the Hudson river, along the west side of which it continues through Greene county to Kingston. An outlier of the Greene county area is found to the east of the river on Becraft mountain near Hudson. The limestones in many places are in close association with the upper members of the Cayugan group, with which they are stratigraphically continuous and closely allied in character. Along the Hudson valley the group attains a thickness of about 200 feet, of which the Coeymans constitutes 50 feet, the New Scotland 100 feet, and the Becraft 35-40 feet. The Coeymans is a heavily bedded, dark gray limestone well adapted for building

stone, crushed stone etc. The New Scotland is an impure shaly limestone with shale intercalations. The most valuable member is the Becraft, which has a light gray color, semi-crystalline texture with pink and white fossils abundantly sprinkled through it; the lower beds contain 95 per cent or so of lime carbonate. It is well shown in the cement quarries around Catskill and Hudson. Lime, flux and building stones are also obtained from these beds. In Schoharie county the Helderbergian limestones are exposed in the quarries at Howes Cave, Cobleskill, Middleburg and other places, where they are worked in conjunction with the Manlius limestone. They extend across southern Herkimer county and appear at Oriskany Falls, Oneida county, with a thickness of about 75 feet, overlying about 50 feet of the Manlius limestone.

The Onondaga limestone is a notably persistent formation that exhibits also much similarity of characters over the long extent of outcrop. The main element is hard fine-grained limestone, containing bands and nodules of chert arranged more or less in courses or as irregular disseminations. This part is the Corniferous, so-called, while below may occur a coarser semicrystalline limestone of considerable purity. The cherty limestone is not much used except for crushing but the more homogeneous layers that are found with it supply also building stone, flux and material for lime manufacture. The outcrop extends across the State from Erie to Albany county, where it turns south into Greene county to near Kingston and thence runs southwest to Port Jervis. The western section in Erie and Genesee counties is marked by a low ridge or escarpment which begins in Buffalo and runs northeast to Akron and thence nearly due east, having the Bertie waterline at the base and the gypsum beds of the Salina lying just north of it. Quarries have been worked in Buffalo, at Williamsville, Akron, Le Roy, Lime Rock and Honeoye Falls. In the lower part of the formation is a stratum of coral rock that is quite pure calcium limestone with 95 per cent or so of the carbonate; this bed is 5 feet thick in Buffalo but increases to 35 feet at Williamsville, only to diminish rapidly again to the east, where it continues as a fluctuating member all the way to Albany county.

Luther¹ estimates the thickness of the Onondaga in the Buffalo district at 168 feet; at the Livonia salt shaft in Livingston county it is 136 feet; in a test well at Ithaca it measures 78 feet; in Onondaga county 65 feet; at Clarksville, Albany county, 85 feet and at Countryman hill, Albany county, 100 feet. In Ulster county it still

¹ N. Y. State Mus. Bul. 99, 1906, p. 13.

measures 60 feet in places. In the vicinity of Syracuse the lower pure beds, locally known as the "gray limestone," have a thickness of 10 to 30 feet; it is extensively worked for building stone, and is recognized as a strong, durable material of attractive appearance. The Split Rock quarries near Syracuse which formerly supplied the limestone used by the Solvay Process Co. partly lie in this layer. The principal building stone quarries in the gray limestone are on the Onondaga reservation, 6 miles south of Syracuse. The Onondaga limestone as exposed in Albany and Greene counties is represented chiefly by the cherty member and is not quarried to any extent. In Ulster county, southwest of Kingston, are a number of quarries which have employed the stone for lime manufacture.

The Tully limestone is confined to the central part of the State. It seldom measures more than 20 feet thick, but has considerable importance for quarry purposes, as it is the only available limestone in the particular section in which it outcrops. Its western limit is in the town of Gorham, Ontario county, whence it follows a winding course southeast to Seneca lake under the depression of which it makes a long loop to the south. It crosses Seneca county to the vicinity of Cayuga lake, of which it parallels the shore for 15 miles on either side, passing under the lake just north of Ithaca. The outcrop then continues across the south end of Owasco lake and of Skaneateles lake, runs across southern Onondaga county and comes to an end in the town of Smyrna, Chenango county. The limestone is low in magnesia, but contains considerable argillaceous matter. It is the basis of portland cement manufacture at Portland Point on Cayuga lake and is employed for local needs of crushed stone and foundation stone at various places along the outcrop.

Analyses of Devonian limestones

	1	2	3	4	5	6	7	8
SiO ₂	3.87	7.1	2.75	4.34	2.52	2.67	1.84	5.12
Al ₂ O ₃	1.07	2.5	1.5	.54	.98	1.23	.63	1.45
Fe ₂ O ₃	1.34	1.65	1.6	1.03			1.82	.74
MgO.....	tr	tr	.....	.19	.37	.96	2.23	2.93
MgCO ₃.....	.....	.....	.....	.....	.....	.....	.....	.....
CaO.....	54.11	45.22	53.1	52.13	53.23	53.26	51.40	48.34
CaCO ₃.....	.....	.....	.....	.....	.....	.....	.....	.....
CO ₂	40.6	39.1	42.1	.....	.....	.....	.....	41.22

Analyses of Devonian limestones

	9	10	11	12	13	14	15
SiO ₂	11.16	1.27	4.31	5.56	2.57	4.45	2.48
Al ₂ O ₃	3.35	.73	.97	{ 1.55	1.55	.3	.95
Fe ₂ O ₃	1.15						
MgO.....			1.65	.83	.84		.46
MgCO ₃	6.65	1.39				5.76	
CaO.....			51.05	50.47	52.69		53.52
CaCO ₃	79.06	97.24				89.4	
CO ₂			41.9	40.57	42.33		42.54

	16	17	18	19	20	21	22	23
SiO ₂	1.92	5.	5.96	14.85	1.17	5.7	6.30	4.50
Al ₂ O ₃	{ .36	{ .6	3.16	7.18	{ .64	2.1	3.35	{ 1.28
Fe ₂ O ₃			1.34	1.57				
MgO.....	.69		1.44	1.95		.67	.22	1.11
MgCO ₃		1.86			1.			
CaO.....	52.53		49.07	40.23		49.56	50.25	51.04
CaCO ₃		92.46			96.54			
CO ₂	42.03		40.13	33.76		39.67		40.88

- 1 Becraft limestone, Rondout. Quarry of Newark Lime & Cement Co. N. Y. State Mus. Bul. 44.
- 2 Becraft limestone, Wilbur, Ulster county. Quarry of J. B. Turner. Idem.
- 3 Becraft limestone, Catskill. Holdridge quarry. H. Ries, analyst. Idem.
- 4, 5 Becraft limestone, near Aisen, Greene county. Lehigh Valley Testing Laboratory, analysts. U. S. Geol. Surv. Bul. 522.
- 6 Becraft limestone, Hudson. Quarry of Knickerbocker Portland Cement Co. H. E. Brown, analyst. Idem.
- 7 Becraft limestone, Hudson. Quarry of New York & New England Lime & Cement Co. U. S. Geol. Surv. 20th Ann. Rep't, pt 6.
- 8, 9 Coeymans limestone, South Bethlehem, Albany county. N. Y. State Mus. Bul. 44.
- 10 Coeymans limestone, Howes Cave. C. A. Schaeffer, analyst. U. S. Geol. Surv. 20th Ann. Rep't, pt 6.
- 11 Coeymans limestone, Barnerville, Schoharie county. C. F. McKenna, analyst. Idem.
- 12, 13 Helderbergian limestone, Oriskany Falls. A. H. Chester, analyst. N. Y. State Mus. Bul. 44.
- 14 Helderbergian limestone, Oriskany Falls. Idem.
- 15, 16 Helderbergian limestone near Clinton. A. H. Chester, analyst. Idem.
- 17 Onondaga limestone, Lime Rock, Genesee county. Idem.
- 18 Onondaga limestone, Leroy, Genesee county. Quarry of Morris & Strobel. Idem.
- 19 Onondaga limestone, Waterloo, Seneca county. Idem.
- 20 Onondaga limestone, Williamsville, Erie county. H. Carlson, analyst. U. S. Geol. Surv. 20th Ann. Rep't, pt 6.
- 21 Tully limestone, near Lansing, Tompkins county. H. Ries, analyst. N. Y. State Mus. Bul. 44.
- 22 Tully limestone, Portland Point, Tompkins county. Middle bed. J. H. McGuire, analyst. U. S. Geol. Surv. 20th Ann. Rep't, pt 6.
- 23 Tully limestone, Dresden, Yates county. W. S. Spackman, analyst. U. S. Geol. Surv. Bul. 522.

MARBLE

Marble, in the commercial sense, like granite, includes a variety of rocks that lend themselves to building or decorative uses. Most commonly, the name signifies a crystalline aggregate of calcite or dolomite, as distinguished from ordinary limestones which at best are of indistinctly crystalline nature. At the same time it implies the feature of attractiveness by reason of color and the ability to take a lustrous polish. Rocks possessing all these features are marbles in the strict sense to which the name may be applied without qualification. Some compact or granular limestones that lack the elements of thorough crystallinity make, however, a handsome appearance when polished, and such are commercially classed as marbles. Fossil marbles, black marbles, and a few other kinds are commonly of the noncrystalline type. Serpentine marble, or verd antique, is made up for the most part of the mineral serpentine, a silicate of magnesium and iron, and is therefore not related to the varieties already described. Ophitic limestone, or ophicalcite, is a crystalline limestone or dolomite carrying grains and nodules of serpentine scattered more or less evenly through its mass. Its ornamental quality lies in the speckled or mottled pattern and the sharp contrast between the clear white mass and the greenish serpentine inclusions.

Marbles belonging to those various types find representation in the geologic formations of the State and are quarried on a commercial scale or have been so quarried in the past.

Distribution. The true or crystalline varieties are limited in occurrence to the metamorphic areas of the Adirondacks and southeastern New York. They are of early geologic age, antedating the period of crustal disturbance and metamorphism which in the Adirondacks was brought to a close practically before Cambrian time and which in southeastern New York was completed in the Paleozoic. This thoroughly crystalline character is in fact a development of the strong compression accompanied by heat to which they have been subjected; having been originally, no doubt, ordinary granular or fossiliferous limestones similar to those so plentifully represented in the undisturbed formations outside the regions.

The crystalline limestones of the Adirondacks are most abundant on the western border in Jefferson, Lewis and St Lawrence counties where they occur in belts up to 4 or 5 miles wide and several times as long, interfolded and more or less intermixed with sedimentary gneisses, schists and quartzites. They are found in smaller and more irregularly banded areas in Warren and Essex counties on the

eastern side, but have little importance elsewhere. The ophitic limestones that have been quarried at different times belong to the same series. The marbles of the Adirondacks comprise both the calcite class, with very little magnesia, and the dolomite class, containing high percentages of magnesia. No definite relation is apparent in regard to the occurrence of the two and both may be found in the same area in close association.

The principal marble quarries in the Adirondack section are found near Gouverneur, within the belt of Precambrian (Grenville) limestones that extends from near Antwerp, Jefferson county, into the town of Canton, St Lawrence county, having a length of some 40 miles and paralleled for much of the distance by the R. W. & O. branch of the New York Central railroad. In appearance it is a medium textured stone of light gray or mottled gray and white, or more seldom solid blue-gray color, that takes a lustrous polish. It is adapted both for building and monumental work. On account of its high carbonate content (95 per cent or more) it has been extensively employed also for lime and furnace flux. There is normally a small proportion of magnesium carbonate (6-7 per cent in most examples) and occasionally this ingredient assumes the proportions of a true dolomite, as instanced by the product of the White Crystal Marble Co., north of Gouverneur. The main quarry section is just southeast of Gouverneur, where the Gouverneur Marble Co., the St Lawrence Quarries and other companies have engaged in quarrying marble for building and monumental purposes. The stone from this section is to be seen in many large structures in the principal towns of New York and adjoining states. Marble has been quarried at several localities near Canton, and also at Harrisville and Natural Bridge, Lewis county.

Serpentine is associated with some of the Grenville limestone of the Adirondacks, producing such varieties as verd antique and ophicalcite that are employed as ornamental stone. Verd antique of handsome appearance has been quarried in the town of Pitcairn, north of Harrisville; it occurs also near Keeseville, Essex county, and at other places. Ophicalcite, mottled white and green marble, occurs in the vicinity of Port Henry and near Minerva, Essex county; small quantities have been employed for monumental and ornamental work.

The southeastern New York marbles occur in belts which follow the north-south valleys, east of the Hudson river, from Manhattan island, into Westchester, Dutchess and Columbia counties. They are commonly white to light gray in color, well adapted for building

stone, of which many examples are to be seen in the commercial structures, churches etc., of New York City. The marbles are mostly dolomites and are interfolded with gneisses and schists, the whole series having steep dips like those of strongly compressed strata. The geologic age of some of the limestones is Precambrian, the oldest being the equivalents of the Adirondack Grenville; in the northern section they may represent regionally metamorphosed Paleozoic limestones. The leading quarries at present are those of the Dover Marble Co., 2 miles northeast of Wingdale station on the Harlem Railroad. They yield a uniform white marble of fine compact texture, that has been in wide demand for architectural purposes. It is a true dolomite. The company has extensive cutting and polishing works at Wingdale station. An important quarry industry existed up to a few years ago in the vicinity of Tuckahoe, Westchester county, where a coarse, brilliant white stone occurs, also a dolomite. The waste from the several quarries has been put to use lately in the manufacture of artificial stone. A very similar marble is found at Pleasantville, Westchester county. Some structural marble has been obtained from Ossining, but the main part of the output from this locality is employed in lime making. Magnesian limestones occur north of Peekskill, in Sprout Brook valley. At Dover Plains, Dutchess county, quarries have been opened in white or bluish-white marble of fine but somewhat loosely built texture. The Dutchess County Lime Co. uses the stone for building and agricultural lime.

Besides the crystalline limestones, some varieties of the bedded granular limestones that occur in the unmetamorphosed Paleozoic series have ornamental qualities that class them in the trade as marbles. Such qualities may be lent by unusual color, by ground pattern due to the variation of grain or the presence of fossils and to the capacity of taking a high polish. Some have a subcrystalline texture which arises from the slow action of ground waters which take the carbonates of lime and magnesia into solution and redeposit them in crystalline form. These limestones have not been generally disturbed by regional forces, but lie in horizontal or slightly tilted beds, in contrast with the macro-crystalline limestones or marbles proper. The black limestone from the Trenton beds at Glens Falls is of this type. It polishes to a uniform black surface and has been employed extensively for floor tiles, mantles and interior work. The Chazy limestone from Bluff Point, south of Plattsburgh, yields a fossil marble characterized by red and pink fragments of crinoids in a gray partly crystalline groundmass. It is

sold for interior decorative work. The Becraft limestone with its round and crescentic fragments of crinoids is worked near Catskill for building and ornamental use.

Serpentine is classed with marble in the decorative stone trade, but is quite different in its mineral and chemical nature, being a hydrated silicate of magnesia that is formed by the alteration of basic rocks in which pyroxene and olivine are important ingredients. Its ornamental quality depends upon the translucency and varied color of the serpentine, ranging from clear white to dark opaque shades of green. Large bodies of this rock occur on Staten island and near Rye in Westchester county, but there has been little quarrying at either locality.

SANDSTONES

Under sandstones are included the fragmental rocks, composed of sand grains compacted or bound together into a coherent mass. The size of the grains may vary from particles of almost microscopic size to those an inch or so in diameter, and this variation is recognized by dividing the group into silts, sandstones proper, and conglomerates. Some sandstones have been simply compacted by pressure, but most of them are bonded by some cementing substance that has been deposited in the open pores between the grains. Upon the nature of the cement and its abundance depend to a large extent the color and strength of the stone. Silica, iron oxide, iron sulphide, iron carbonate, calcium carbonate and clay are the commoner kinds of cement in sandstones. Silica produces the hardest, most durable bond and when the grains themselves have a similar composition the material is known as quartzite. Iron oxide affords a permanent bond, but iron sulphide decomposes readily on exposure to the atmosphere and sandstones in which it enters to any extent are unsuitable for constructional purposes.

Of the sedimentary rocks which occur in New York State, sandstone is one of the most widespread geographically but in economic importance it ranks second to limestone. Nearly all of the recognized stratigraphic divisions above the Archean contain sandstone at one or more horizons. The kinds chiefly quarried are the Potsdam, Hudson River, Medina and Devonian sandstones. A few quarries have been opened also in the Shawangunk conglomerate and the Clinton and Triassic sandstones.

Potsdam sandstone. The Potsdam, a member of the Cambrian system, is the oldest and lowest of the formations that contain sandstones in extensive areal development adapted to building

and general purposes. The principal exposures are on the northern and northwestern sides of the Adirondacks. A continuous belt of the Potsdam from 5 to 15 miles wide extends from Lake Champlain across Clinton, Franklin and St Lawrence counties into Jefferson county and to the St Lawrence river, as a border to the Precambrian crystalline formations upon which the sandstone lies. Additional though smaller outcrops occur on the east side of the Adirondacks in Essex, Washington, Warren and Saratoga counties, and on the north side of the Mohawk valley. They represent faulted and eroded patches of once extensive belts of the sandstone that reached well toward the interior of the highlands.

The Potsdam, in places shows the character of quartzite, having a body of quartz sand cemented by a secondary deposit of quartz, and is then exceedingly hard, tough and durable. There is no stone more resistant to weathering or better qualified to withstand heavy strains. Samples have sustained a crushing strength of more than 42,000 pounds to the square inch. The quartzite has a clear white, pink to light red color, varying considerably in different beds. Deep red colors which are occasionally to be seen imply the presence of ferric oxide in considerable amount. As a rule the beds are rather thin and their surfaces are often uneven owing to ripple marks. The edges have a laminated appearance, especially in the darker colored stones. Cross-bedding is not uncommon. The Potsdam bears an excellent reputation as a building stone, and the only difficulty with its employment for the purpose inheres in its refractory character in regard to sawing and tool treatment. For that reason it is used mostly in rock-face ashlar work. Many important structures built of the pink and light red stone are to be seen in the principal towns and cities of the State.

Quarries in the Potsdam have been opened at Clayton, Chippewa Bay, Hammond, Redwood, Potsdam, Malone, Bangor, Moira, Burke and other places in the northern belt; also at Keeseville, Port Henry, Whitehall and Fort Ann in the Champlain valley; and near Keck Center in the Mohawk valley. The principal sources of building stone have been the quarries near Potsdam and those near Malone and Burke, Franklin county. The Potsdam Red Sandstone Co. has supplied much ashlar from the quarries 3 miles southeast of Potsdam. At Burke flagstone has been quarried, largely for use in Montreal.

The white Potsdam quartzite is a high-silica material that has found application in years past for glass manufacture. The purer beds carry 98 to 99 per cent or more SiO_2 , as exemplified by the

Moira and Bangor occurrences which were once worked for glass material. The iron content is low, 0.05 per cent or less in the best grades. It is possible in some instances to improve the quality by washing, as the sandstone may have a crumbly texture so as to be readily reduced to a sand. A sample from Moira thus treated, showed silica 99.54; iron 0.0054. Large quantities of the sandstone are sufficiently pure to be used for ferro-silicon manufacture.¹

Hudson River beds. The so-called Hudson River series includes a great thickness of sandstones and shales which possess a certain uniformity of character and field development but which are really composite of several stratigraphic units, ranging in age from Trenton to Lorraine. The sandstone members are usually fine-grained, not infrequently of the character of silts, light gray to dark blue gray in color. The stone weathers to a brownish yellow tint. It has a tendency to split or scale on exposure, especially the silty layers. The better grades have a siliceous binder; the clayey and calcareous varieties are to be avoided. Some of the quarries afford rectangular blocks with natural joint surfaces which have a soft brown or yellow tone, desirable for architectural work. A number of structures in Albany and vicinity are built of such stone. Over considerable areas the sandstones supply the most available material for foundation and general construction purposes and consequently they have been quite extensively used.

The sandstones with the accompanying shales are exposed over a wide belt along the middle Hudson from Washington and Saratoga counties south to Dutchess and Orange. A second belt reaches up the Mohawk as far as Oneida county. It is only here and there that they are in sufficient force to be quarried, as a rule they occur in thin beds intercalated with the shale.

Much of the building stone has been obtained in Schenectady and vicinity, while quarries for rubble and foundation stone have been worked at Rhinebeck, New Baltimore, Troy, Albany and other places. The Schenectady quarries afford the natural joint face ashlar to be seen in many churches and public buildings in that city, Albany and Troy. Crushed stone is produced at Schenectady and Albany.

Medina sandstone. This is one of the most extensively quarried sandstones in the State and is highly esteemed for general building and construction purposes. The better grades which consist of

¹ The information on the chemical character of the sandstone has been supplied by Mr R. J. Colony, who has undertaken an investigation of the high-silica materials of the State.

the straight, even grained, well bonded, quartz sandstone, rank with the best freestones of the country. Examples of its architectural use may be seen in the larger cities of the State — Buffalo, Rochester, Syracuse, New York — and also throughout the middle west; while it has had equal favor for street work. It is quite resistant to weather and the well bonded sorts do not readily crack or "open" if laid on edge. In recent years the demand for architectural stone has diminished to such an extent that the product now sold for that purpose is a small item in the total; paving blocks, cross-walks and curbstone being the principal kinds produced.

The Medina sandstone is typically a quartz sandstone with a ferruginous or siliceous bond. The grain is medium to coarse. Cross-bedding is not very common, the lamination being usually straight. The individual beds range up to 5 or 6 feet thick. Thin argillaceous sandstones are also found in the series, as a gradation to the shales which lie below the coarser sediments. A parting of red shale may also lie between the sandstone layers and is known as "red horse." In depth, as the level of ground water is reached, pyrite is likely to appear in knots within the stone and as films upon the joint surfaces. The color is light gray, pink, or variegated in the two tints. The gray stone is locally called "white" Medina. In limited amount occurs a reddish-brown variety which is in most demand for building purposes.

The Medina formation extends along the southern shore of Lake Ontario in a belt about 10 miles wide. It contains an assemblage of shales and sandstones altogether about 1200 feet thick in their extreme development. The sandstones in which the quarries are located lie in the upper 150 feet of the formation and usually just north of the ridge which marks the outcrop of the Niagara dolomite. The area underlain by the beds is quite flat and the quarries are in the form of pits or trenches, with 5 to 15 feet of glacial cover and 20 to 30 feet of rock face. It is not possible as a rule to carry the excavations deeper than this on account of the ground water which lies close to the surface in most places. The selection of quarry sites has been made with reference to transportation facilities supplied by the canal and railroad lines, most of the present quarries lying along the old Erie canal.

The principal operations are carried on in Niagara and Orleans counties in the stretch from Lewiston to Holly. In the Niagara section the output is represented largely by light gray stone which is obtained from near the base of the quarry face. There has been little demand of late years for this variety as building stone. The

gray beds become less prominent as the strata are traced into Orleans county which produces pink, variegated and red stone. There is almost a continuous string of openings across this county following the course of the Erie canal, with Medina, Eagle Harbor, Albion, Hulberton and Holly as the principal shipping points. Some of the largest operations in this section are the Orleans County Quarry Co., M. A. Ryan, Reed, Allen & Reed, John I. Cleary, Albion; Clark Bros. Quarry Co., Fancher; Moore & Waite, Vincent Stone Co., Thomas Vincelli, Hulberton; Orleans Sandstone Co., Holley. Orleans county by itself accounts for more than one-half of the production of sandstone, other than bluestone, reported for the whole State.

Shawangunk conglomerate. This includes a series of arenaceous beds, conglomeratic at the base but with sandstone and shaly layers above, of Silurian age, outcropping in Orange, Sullivan and Ulster counties where it forms the prominence known as Shawangunk mountain. The strata extend in a continuous belt from High Falls near Kingston southwest into New Jersey at Port Jervis. They form the steep northwest face of the mountain and their dip is practically that of the surface slope that is to the northwest at angles of 25° to 45° . They attain a maximum thickness of about 200 feet.

The sandstones are gray, hard quartzites of firm texture. The coarser layers have been extensively quarried for millstone. They are employed locally for rubble and foundation work, and at Otisville quarries have supplied large quantities of stone for ballast and abutment work in improvements carried out by the Erie and the Ontario and Western Railroads. A crushing plant at this place is operated by Bull & Wilbur, Incorporated.

Clinton sandstone. Sandstone is an important member of the Clinton beds of eastern New York, although usually absent from the western section. In Herkimer and Oneida counties it occurs in successive layers that attain a thickness of 40 or 50 feet and occasionally forms ledges that can be easily quarried. It is a reddish brown to gray freestone, fairly hard and even grained, well adapted for ordinary construction work. It has been employed locally for architectural work of which examples are to be seen in some of the Utica churches. No large quarry operations are carried on at present.

Devonian sandstones. The Devonian sandstones that yield structural materials are mainly found in the upper portion of the system, within the Hamilton, Portage, Chemung and Catskill for-

mations. Collectively they are the most widespread of all in surface development, since practically all of the middle and southern tiers of counties, west of the Hudson river, are underlain by Devonian beds — chiefly sandstones and shales — covering an area of fully one-third that of the whole State. The northern and eastern limits of the Devonian beds may be defined approximately by a line drawn from Port Jervis in Orange county, northeast to Kingston and thence north on the west side of the Hudson river to Ravena below Albany where the boundary swings in a broad curve to the northwest following the Helderberg escarpment into Schenectady county; from this locality it continues in a direction north of west, parallel with the Mohawk river, into Oneida county, south of Utica; thence the boundary extends almost due west to Buffalo and Lake Erie. Within the area thus defined the strata all belong to the Devonian with the exception of a few patches of Carboniferous conglomerate in Allegany and Cattaraugus counties on the Pennsylvania border. The predominant rock type over large areas is shale, but in most sections sandstones are found intercalated with the shale or in successive beds which may reach considerable aggregate thickness.

The Devonian sandstones are commonly grouped together for commercial purposes under the name of bluestone. This name, it appears, originated among the quarrymen of Ulster county, where the characteristic material in the quarry ledges has a bluish gray color. There is no broad significance to the term, however, for drab, green and purple to red varieties are associated with the blue layers, and outside of the Hudson River district they are quite common. The special properties of these sandstones are sufficient reason to place them in a separate class, and the term bluestone may well be retained as a general group name.

They occur in thin-bedded layers or flags, which gradually thicken in depth below the zone of frost action. They have a fine, compact, even texture, giving the appearance of a uniform dense mass that in the finer-grained phases is really a silt. In conformity with the closeness of grain the stone has a low porosity and absorbs moisture to a small extent, whereas most sandstones are fairly porous and form the natural reservoirs for storage of water, gas and oil. A further character that is found in many of the quarries is the well-developed capacity for parting along planes parallel to the bedding. By reason of this property the heavier layers may often be split into two or more slabs with smooth even surfaces, so as to be readily converted into curb or flagstone. The expert quarryman is able to recognize the lines of potential parting on the edge of the stone

by the variation in texture; the lines are called "reeds." If the stone lacks "reeds" it usually breaks with a conchoidal fracture and is then said to be "scallop." By virtue of the reeds the stone may be worked up into commercial form with a minimum of labor. The thicker stone is utilized for curbing, crosswalk and large platforms; the thinner is sold as flagging or in part cut into dimension form for sills, lintels, window caps and other house trimmings. Dimension stone for building purposes is mainly produced in the Wyoming county quarries where the stone has a softer texture and can be readily shaped in the mill.

The Hudson River bluestone district includes parts of Albany, Greene and Ulster counties, where the stone quarried is brought out to the river for shipment by boat. Albany, Catskill, Saugerties and Kingston have been the main collecting points for the product along the river; in recent years very little stone has been produced in the area tributary to Albany or Catskill, so that Saugerties and Kingston have become the only important centers of the business. In Albany county there are quarry sites in the towns of Berne, Westerlo and Coeymans, from which stone was formerly obtained. They have not been productive for the last 10 years. Greene county once shipped considerable stone from quarries located along the edge of the Catskills and from some of the interior towns which are on the line of the Ulster & Delaware Railroad. Ulster county has always been the main factor in the industry of this section; the principal quarry localities, many of them now abandoned, are situated in Saugerties, Kingston, Hurley, Woodstock, Shandaken and Olive townships. In the town of Saugerties are Quarryville and West Saugerties, both important for the industry. The output in Ulster county has been handled of late years by the firm of John Maxwell's Sons, Saugerties, and the Hudson River Bluestone Co., Kingston.

The Delaware River district includes Sullivan, Delaware and Broome counties, tributary to the Erie and Ontario & Western Railroads, over which most of the product is shipped. The quarry centers and shipping points include Walton, Hancock, Lordville, Hale Eddy and Fish's Eddy, Delaware county; Rockland, Livingston Manor and Long Eddy, Sullivan county; and Deposit, Broome county. Some of the larger quarry operators and dealers are Deposit Stone Co., Deposit; Kirkpatrick Bros., Hancock; M. L. Connor & Son, Walton; Travis Stone Co., Hale Eddy; Johnston & Rhodes Bluestone Co., Horton; Herbert Shaw, Middletown; Kenney Bros., Long Eddy; and William J. Reynolds, Roscoe.

In Chenango county large quarries are found near Norwich and Oxford. The stone from this section occurs in heavy seams, and though resembling the product of the Ulster county quarries in its color and fine even grain, is not so hard. The upper beds of thinner stone are sold for flag and curbstone and the heavier ones are worked into building stone, which forms the chief item. Much of the product is shaped in the mill. Clark, Conroy & Co., Norwich; Graham & Aylesworth, Oxford; and McNierney Bros., Oxford; operate in this district.

Near Warsaw and Portageville, Wyoming county, are quarries that supply building stone in large quantity. The layers or "lifts" are heavy, fine grained, and easily milled. The sandstone is of Portage age.

Bluestone quarries have been worked in most of the southern tier of counties from Broome county west to Cattaraugus county, but the product is mostly for local use and the operations are desultory.

Triassic sandstone. The area of Triassic rocks (Newark series) in Rockland county includes arenaceous beds of workable dimensions that yield a red coarse-grained freestone. They are exposed along the face of Tor mountain near Haverstraw, and south of there at intervals as far as Piermont. Quarries were once worked for local supply of building and foundation stone, but have long been idle.

TRAP

Trap is not a distinct rock type, but the name properly belongs to the fine-grained, dark-colored igneous rocks that occur in intrusive sheets and dikes. In mineral composition it differs from most of the igneous rocks that are classed in the trade as granite by the prevalence of the basic plagioclase feldspars and the higher percentages of the iron-magnesia minerals, while it contains no quartz. Some of the so-called "black granites," however, are trap. The name is sometimes applied to fine-grained rocks of sedimentary derivation, but such usage is misleading and indefensible.

The particular value of trap is due to its hardness and toughness. Its fine, compact, homogeneous texture gives it great wearing powers and it is eminently adapted for road metal and concrete of which heavy service is required. The principal product, therefore, is crushed stone. It has been used to some extent, also, as paving blocks, but these are rather difficult to prepare, since trap very seldom shows any capacity for parting comparable to the rift and

grain structures of granites. As a building stone it finds very little application, probably on account of its somber color. The expense of cutting and dressing trap is also an obstacle to its employment for building or ornamental purposes.

The trap quarried in New York State is properly a diabase. Its mineral composition varies somewhat in the different occurrences, but the main ingredients are plagioclase feldspar and pyroxene, with more or less of amphibole, olivine, magnetite and sometimes biotite. The texture is characteristic, for the feldspar forms lathshaped crystals which interlace and inclose the pyroxene and other ingredients in the meshes, and it is this firmly knit fabric which gives the stone the qualities of strength and toughness.

Occurrence. The largest occurrence of trap in New York is represented by the Palisades of the Hudson and the continuation of the same intrusion which extends southward through New Jersey onto Staten island and is also encountered in the interior of Rockland county. The Palisades are the exposed edge of a sill or sheet of diabase that is intruded between shales and sandstones of Triassic age. The sheet is several hundred feet thick, in places nearly 1000 feet, and in general seems to follow the bedding planes of the sedimentary strata which dip to the west and northwest at an angle of from 5° to 15° . The outcrop is narrow, seldom over a mile, and in places is limited to a single steep escarpment. The principal quarries are near Nyack and Haverstraw at the base of the cliffs. Other quarries have been opened near Suffern, Rockland county, on an isolated intrusion, and also near Port Richmond, Staten island, at the southern end of the Palisades sill.

Trap occurs in numerous places in the Adirondacks, but mostly as narrow dikes. It is especially common in Essex and Clinton counties, where there are many thousands of dikes that range from a few inches to 20 or 30 feet thick. On the southern border of the region are a few dikes of notable size, such as that in the town of Greenfield, Saratoga county, and at Little Falls in the Mohawk valley. A quarry has been opened in the Greenfield occurrence for the supply of crushed stone.

The quarrying of trap along the face of the Palisades in Rockland county probably will soon be discontinued, as it is designed to purchase the quarry properties for the Palisades Interstate Park. The lands to be included within the park extend from the river line to the top of the Palisades. So far only the quarry of the Manhattan Trap Rock Co. has been taken over and closed, but nego-

tiations are proceeding for the acquirement of the other quarries along the river front.

The future of the industry in this section is somewhat unsettled. It is not unlikely that new quarries may be opened on top of the ridge and in the interior of Rockland county, though the facilities for production and shipment in that section can scarcely be equal to those of the present localities.

References to Stone

- Dickinson H. T.** Quarries of Bluestone and other Sandstones in New York. N. Y. State Mus. Bul. 61, 1903
- Eckel, E. C.** The Quarry Industry of Southeastern New York. N. Y. State Geol. 20th Ann. Rep't, 1902
- Hall, James.** Report on Building Stone. N. Y. State Mus. 39th Ann. Rep't, 1886
- Geology of New York. Rept. on Fourth District, 1843
- Mather, W. W.** Geology of New York. Report on First District, 1842
- Merrill, F. J. H.** Mineral Resources of New York, N. Y. State Mus. Bul. 15, 1895
- Merrill, George P. & Others.** The Building Stones of the United States. Report of the 10th Census, v. 10, 1884
- Newland, D. H.** The Quarry Materials of New York—Granite, Gneiss, Trap and Marble. N. Y. State Mus. Bul. 181, 1916
- Smock, John C.** Building Stone in the State of New York. N. Y. State Mus. Bul. 3, 1888
- Building Stone in New York. N. Y. State Mus. Bul. 10, 1890
- Vanuxem, Lardner.** Geology of New York. Report on Third District, 1843

STRONTIUM

The principal strontium minerals are celestite, the sulphate, and strontianite, the carbonate; both are clear, transparent or translucent white substances that resemble the corresponding barium compounds. They are found in veins, geodes and concretionary masses, usually in limestone country and frequently associated with calcite. Barytocelestite is a mixture of the sulphates of barium and strontium. Unlike barite, celestite finds little employment in its natural state, but is used for the preparation of other salts.

The strontium compounds have rather limited applications in industry. Until recently they have not been in large request and most of the requirements have been supplied by imports from abroad. The chief commercial salt is the nitrate which is consumed mainly in the manufacture of fireworks and night signals, being employed to produce the red color that is characteristic of strontium compounds when heated to incandescence. Recently a demand has developed for the hydroxide in connection with sugar refining, particularly in the beet sugar industry, of which the use is said to

effect an increased extraction of the saccharine content of molasses over the usual methods. This application may result in a more extensive demand for the compounds, of which the normal consumption in this country is said to amount to about 2000 tons a year.

Occurrence. Strontianite, the carbonate, is found in the vicinity of Schoharie. The single deposit that has been worked lies 2 miles north of Schoharie village on the face of Terrace hill, within sight of the road leading to Schoharie Junction. The occurrence is said to have been found by John Gebhard, who also established the presence of strontium minerals in several places in the vicinity. It consists, so far as can be learned at the present time, of a fissure in limestone which carries geodelike masses of white strontianite. The mineral resembles white compact calcite or marble in appearance. The deposit was worked in a small way through a drift extended from the hillside at the base of the cliff, and the product lowered in buckets on a wire cableway. There is no record available as to the success or extent of the operations.

The occurrence of strontianite with barite is reported also in the limestone strata east of Schoharie village. According to an early account of the Schoharie deposits by Prof. C. U. Shepard¹ it would appear that several forms of the mineral are to be found in this vicinity, including well-developed crystals of variable habit.

A mixture of some strontium mineral (perhaps strontianite) with calcite, possibly barite, pyrite and more or less clayey matter forming nodular masses of varying size, is to be seen in the Brayman shales as exposed along the west side of Schoharie creek, on the John Gebhard place. The locality has been prospected in a small way for pyrite; but the occurrence of the strontium minerals seem to have escaped notice. The mixture of the different substances is so intimate that the character of the strontium compound is not readily apparent, although it is present in sufficient proportions to give a red flame where a piece of the material is moistened with acid and heated over a burner. Further investigation of the occurrence is to be made.

Celestite, according to Grabau², occurs in the Rondout waterlime, east of Schoharie village. A deposit of blue gray celestite in tabular crystals has been obtained in considerable abundance from the waterlime in the cliff east of Schoharie. Loose specimens are found in the stone fences and may be recognized by their color, crystal form and great weight. The mineral was examined by

¹ Amer. Jour. Sci., v. 27, 1835.

² Geology and Paleontology of the Schoharie Valley, N. Y. State Museum Bul. 92, p. 360-61, 1906.

Dr V. J. Chambers of Columbia University, who found it to be strontium sulphate, with some barium sulphate admixed. From this analysis it appears that the mineral is in reality barytocelestite.

The Schoharie occurrences seem to deserve investigation as possible sources of strontium minerals, if these should come into considerable demand in the future.

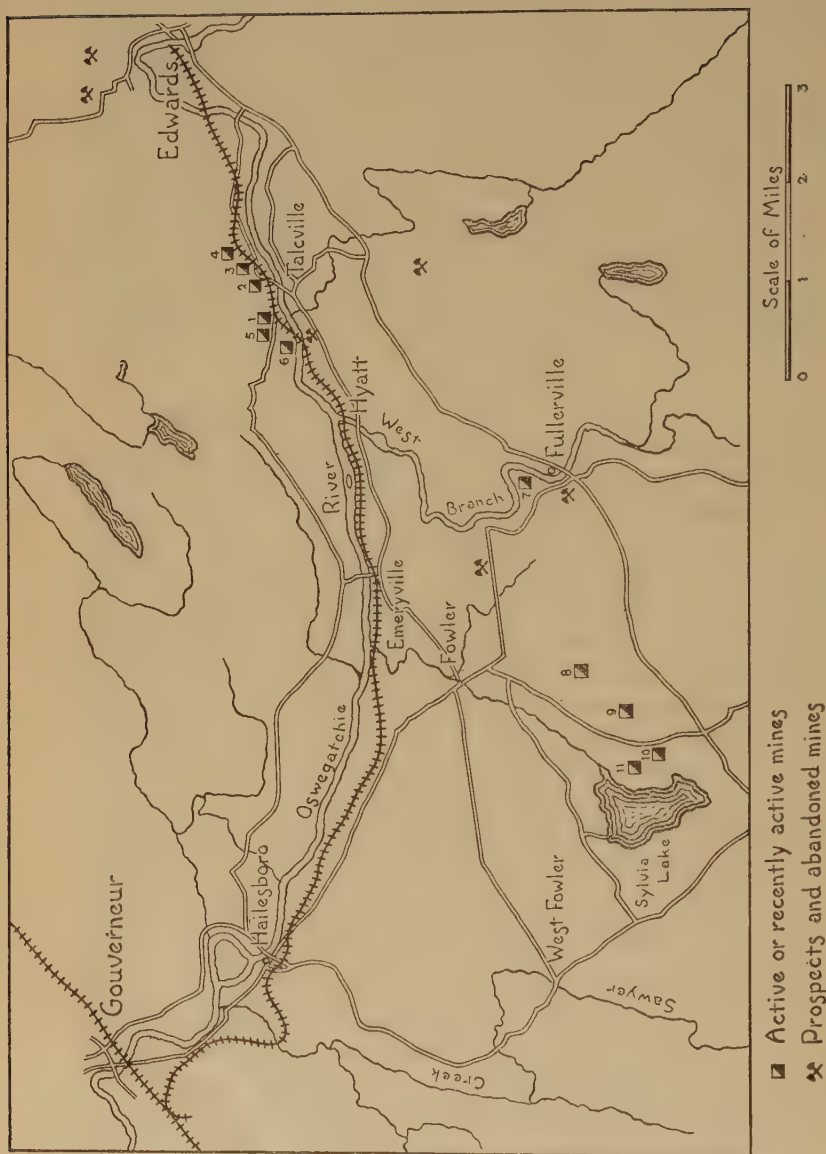
Celestite has been noted at Starkville, Herkimer county and in several localities in Jefferson county, notably at Brownville, Depauville, Chaumont and Theresa. It occurs at the Rossie lead mines in small amounts in association with calcite. At Lockport it is found as crystals in geodes with calcite, dolomite and gypsum, inclosed in the Lockport dolomite. It is not likely that any of these occurrences have commercial interest.

TALC

Talc occurs in important deposits and for many years has been actively mined in the State. The principal supply of the mineral has been obtained from the Edwards district, St Lawrence county, where the deposits occur in crystalline magnesian limestones of Precambrian age, which also are the sources of the newly developed zinc ores. The district includes the belt of limestones that extends from Sylvia lake, town of Fowler, into and across the adjoining town of Edwards, with an area of some 20 square miles. A second parallel belt of the limestones to the south, extending into Lewis county, contains a deposit of talc in the vicinity of Natural Bridge which has been under exploitation in recent years.

The talc industry during 1917 and 1918 showed a continuation of the favorable market conditions that obtained in the preceding years, stimulated by the widespread industrial activity and by the necessity of utilizing the domestic product in the place of foreign grades which previously had been freely imported but of which shipments in the last year or two have been greatly curtailed. In the same way the diminished importations of white clay for coating papers has enlarged the field for grades of talc applicable to that use. The fibrous talc of St Lawrence county occupies a special place in the paper industry by reason of its physical texture.

The production of the talc mines in 1917 showed a decline from the record total of the previous year, for which local conditions, and especially the inadequate labor supply, may be held responsible. The output in 1917 was 74,671 short tons, valued at \$881,462, as compared with 93,236 tons valued at \$961,510 in 1916. In 1918 the production amounted to 71,167 short tons valued at \$902,100.



■ Active or recently active mines
 ✕ Prospects and abandoned mines

The Edwards talc district, St. Lawrence county.

Nos. 1, 2, 3, 4, shafts of the International Pulp Co. No. 5, shaft of the United States Talc Co., now out of business. No. 6, shaft of the Uniform Fibrous Talc Co. No. 7, shaft of the Ontario Talc Co., now out of business.

The average selling price based on the above figures was \$12.68 a ton in 1918 as compared with \$11.81 a ton in 1917 and \$10.30 in 1916.

Altogether the output of talc in the State has amounted to about 1,950,000 tons, valued at \$16,500,000. Shipments began to assume importance about 1880, but talc was mined on a small scale before that date which, however, marks the inauguration of continuous mine operations in the Edwards district.

Production of talc in New York

YEAR	SHORT TONS	VALUE	YEAR	SHORT TONS	VALUE
1883.....	6 000	\$75 000	1901	62 200	\$483 600
1884.....	10 000	110 000	1902	71 100	615 350
1885.....	10 000	110 000	1903	60 230	421 600
1886.....	12 000	125 000	1904	65 000	455 000
1887.....	15 000	160 000	1905	67 000	519 250
1888.....	20 000	210 000	1906	64 200	541 600
1889.....	23 476	244 170	1907	59 000	501 500
1890.....	41 354	389 196	1908	70 739	697 390
1891.....	53 054	493 068	1909	50 000	450 000
1892.....	41 925	472 485	1910	65 000	552 500
1893.....	36 500	337 625	1911	65 000	552 500
1894.....	50 500	454 500	1912	61 619	511 437
1895.....	40 000	320 000	1913	63 000	551 250
1896.....	46 089	399 443	1914	74 075	671 286
1897.....	57 009	396 036	1915	69 514	576 643
1898.....	54 356	411 430	1916	93 236	961 510
1899.....	54 655	438 150	1917	74 671	881 462
1900.....	63 500	499 500	1918	71 167	902 100

Nature of talc. Talc is a hydrated magnesian silicate, which in pure state contains: silica 63.5 per cent, magnesia 31.7 per cent and water 4.8 per cent. The mineral is both a primary deposit from solution and a secondary product resulting from the alteration of an anhydrous magnesian silicate of the amphibole and pyroxene groups. Primary talc shows crystal properties, occurring as flakes and scales that have well defined physical characters, and chemically is close to the theoretical percentages demanded by the formula. Secondary talc frequently preserves the structure and habit of the parent substance, so that its form is without significance in regard to its own crystal development, and it is often admixed with impurities that were contained in the primary silicates.

The talc in the Edwards district is principally secondary and pseudomorphic talc, derived by alteration of tremolite whose physical structure is still retained. The talc occurs in small elongated to squarish particles, made up of many parallel fibres; and these fibrous aggregates are intergrown so as to constitute a solid mass

of schistose appearance. To the unaided eye the rock appears homogeneous, but when examined more carefully with the aid of the microscope it is usually observed to contain more or less residual tremolite that has not succumbed to the alteration process. The conversion of tremolite to talc requires one molecule of water for each tremolite molecule. It is, however, not simply a process of hydration, since the tremolite contains about 13 per cent lime (CaO) which is discharged from the combination and becomes free to associate with any available acid radical.

Foliated or crystal talc is present to a minor extent in most of the occurrences in the Edwards district. It occurs in seams and other openings, where it has been deposited doubtless by waters circulating through the deposits, to which the conversion of tremolite into the fibrous mineral is ascribed. That some of the talc should be taken into solution and reprecipitated apart seems only natural. In one mine (Balmat) the two varieties occur in contiguous layers, the foliated talc forming a seam on the hanging wall, unmixed with the fibrous mineral.

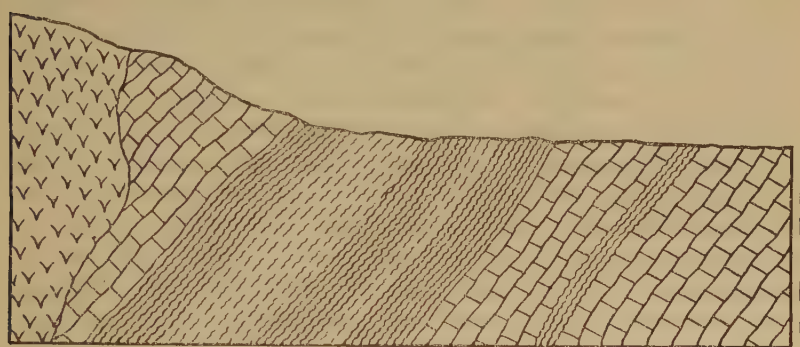
Massive talc that has no definite structure or texture is the variety found at Natural Bridge. It appears homogeneous and dense in the specimen, but microscopically is an aggregate of minute grains and scales whose precise character is not always apparent. The product of this locality is probably a mixture of several minerals of secondary nature, including serpentine, chlorite and kaolin, as well as talc. Its derivation is uncertain, as no traces of the original anhydrous minerals were to be seen in the many samples that have been examined.

Analyses of New York talc

	1	2	3	4	5
SiO_2	60.59	59.92	62.10	68.9	48.16
Al_2O_3	.13	.50	.....	1.3	7.43
Fe_2O_3.....	.....				
FeO	.21	.....	1.30	.....	3.15
MnO	1.16	.76	2.15	.....	.....
MgO	34.72	31.37	32.40	26.6	27.44
CaO}.....	.....	.57	.....	.8	.25
Na_2O}.....	.....	.48	.....	.....	.....
H_2O	3.77	6.25	2.05	2.4	13.74
Total.....	100.58	99.85	100.00	100.0	100.17

- 1, 2 Fibrous talc, Edwards district, Dana's System of Mineralogy, p. 679.
 3 Fibrous talc, Edwards district, N. Y. State Mus. 49th Ann. Rep't, v. 2, p. 670.
 4 Fibrous talc, Talcville, Edwards district. Communicated by A. McLintock.
 5 Massive talc, Natural Bridge, R. W. Jones.

Methods of occurrence. The talc deposits consist of bands, lenses and irregular masses enclosed by the Grenville limestones and schists. One or both walls may be limestone; but in some deposits the talc is bordered on one side by unaltered tremolite schist, the line of demarcation between the two materials being well defined. They are not veins, except as that name may be applied to the small bodies of foliated talc that fill openings within the other, but represent portions of the tremolite schist that have been subjected to alteration underground through the agency probably of deep-seated circulations. It is certain that the talc is not a product of surface weathering.



Generalized section of the Edwards talc deposits

The individual deposits conform in structural features with the wall rocks, having usually a northeast-southwest trend which is that of the limestones but showing minor plications and crumplings and small faults seldom observable in the limestone. The dip of the deposits is to the northwest at angles that usually lie between 30° and 60° , but which occasionally reach nearly verticality. It may vary extensively in the same deposit, through the presence of rolls by which the dip changes abruptly with more or less regularity, and through the gradual steepening of the inclination with depth which is a common experience.

The lenticular form of deposit seems most common, though every variation from the type may be found. The thickness of the deposit from wall to wall seldom exceeds 30 to 40 feet, while the dimensions

along the strike and dip are measured usually by hundreds of feet. The thickness is greatest ordinarily near the middle of the deposit as seen on the surface and gradually diminishes in either direction. The extent of the deposits on the dip is unknown, but exceeds the depths attained by mining up to the present time, which are about 700 feet in the deepest shafts, measured on the plane of the dip.

The talc bodies are distributed mainly along the borders of the limestone area, in the section from Sylvia lake to Edwards. Although they occur rather irregularly, most of the deposits may be grouped into two main belts extending northeast-southwest parallel with the limestone-gneiss contact. One of these is in the southwestern end of the district and on the southern margin of the limestones. Within it lie the Balmat, Wight and Arnold mines, of the former Union Talc Co., recently operated by the International Pulp Co., and the mine formerly worked by the Ontario Talc Co., also the shaft and prospects on the property of the Dominion Co., near Sylvia lake, northwest of the Balmat. This belt is about 3 miles long and the talc occurs within a short distance of the gneiss foot wall which here consists of a dark amphibolitic rock that is injected by red granite. The second belt is northeast of the first and on the opposite side of the limestone area; the strata here dip below the gneiss, which also is an injected type, and contain the mine of the Uniform Fibrous Talc Co., on the Oswegatchie river below Talcville, the old United States mine at Talcville, and the several openings of the International Pulp Co., including Nos. 2½, 3, 4 and 5, in the stretch between Talcville and the first mile northeast of that village.

It is not uncommon to find two or more layers of the talc, in overlapping arrangement. As many as four parallel layers are known at a single locality, separated by intervals of unchanged tremolite and of limestone. In the exploitation of the deposits it has been found that the pinching out of a body as it is followed along the strike or dip may be accompanied by the appearance of a second layer in the hanging or foot wall which can be tapped by a short cross-cut.

Mining practice. Mining is carried on underground, although in the early days open-cut methods were in use on the outcrop of the deposits. The general practice in the district does not differ materially from that followed in working ore deposits that are similarly situated, though of course the soft and slippery nature of the material necessitates certain modifications, especially in regard to pillar supports which have to be of large size. The workings are reached through inclines carried down on the footwall. If the bed is not over

15 feet or so thick, a single horizontal drift is run from either side of the incline following the strike, at intervals of from 50 to 75 feet. The drift is carried the full width of the bed and connections made by raises with the next level above; after which the talc is removed between the levels, leaving pillars 25 feet or more square, at intervals varying with conditions, to support the roof. With a bed of greater thickness two parallel drifts may be run on the same level, leaving a wall of talc between for support. Heavy pressure on a pillar is liable to bring about its collapse by dislocation at the top or base, especially as there is often a gouge or narrow parting on the one side or the other of the talc.

Drilling is performed by machines of the percussion type and the holes loaded with dynamite. The talc splits readily along the cleavage planes, following the schistosity of the original tremolite, so as to form slabs which if too large to handle are broken up by sledges. The broken rock is loaded into cars and trammed to the incline, where it is dumped into skips and hoisted to the surface.

The principal drawback to mining is the considerable and often large flow of water that is invariably encountered, the handling of which necessitates extensive pumping equipment. The water percolates more or less all through the walls, but the main flow is usually from open seams which are encountered in the extension of the drifts and which represent faults or crush zones that extend into the country rocks so as to admit of extensive and deep circulations. The water is of surface origin but may be collected from a large area. If the flow is excessive — beyond the capacity of the pumping equipment — the best plan seems to be to wall up the chamber in which it is encountered.

There is no uniform practice in selecting or grading the talc before it is sent to the mill. In most mines the foliated talc forms such a small percentage of the whole that it does not affect the quality of the ground product. Certain mines of the southwest end in the town of Fowler yield considerable quantities of the crystal talc, which is kept apart and shipped separately for making special grades of ground talc. It produces a very soft smooth product, lacking the fiber of the more common variety. The attention of the mine workers is directed to the extraction of as little of the unaltered schist and of the gritty talc as possible, and where practicable such material is left in the walls and pillars. Besides tremolite there is often more or less free quartz in the fibrous talc. The presence of grit is particularly objectionable in paper stock on

account of the incidental wear and damage in the rapid operations of paper manufacture as carried on in most mills.

Many of the mines are owned independently of the operative companies, to whom they are leased on a royalty based on a specified amount per ton and requiring the extraction of a certain minimum tonnage each year. The royalties vary rather widely, but in every case are rather high for a low-priced product like talc, of which the cost of preparation is proportionately high. The royalties on some properties run as high as 75 cents a ton; and the lowest reported are around 25 cents a ton.

Milling. The reduction of talc to the degree of fineness ordinarily required of the product is a simple but not inexpensive process, which requires an extensive equipment of crushing and grinding machinery. Talc is one of the softest minerals known, yet in the natural state possesses a degree of cohesion and toughness which renders its comminution no easy matter. This is true in regard to both the felted fibrous variety and the foliated talc; massive talc may be more easily pulverized.

In St Lawrence county processes now employed have been gradually evolved from experimentation extending over a long period of years. The first output was ground in buhrstones, like those employed in grain mills. The demands of consumers have necessitated the adoption of more elaborate methods that can be depended on to yield the desired quality and uniformity of grade.

Practically all the output is ground in the district by milling plants situated along the Oswegatchie river, which supplies most of the power thus used. They are distributed along the river from Talcville, 2 miles below Edwards, to Hailsboro, 3 miles above Gouverneur. Altogether the mills have a combined capacity of nearly 100,000 tons of prepared talc a year; but the full capacity has never been continuously employed.

The grinding of the talc is accomplished in several stages. The process varies with each mill, as there is no standard practice further than that the final stage is always carried out in revolving cylinders loaded with pebbles. The first step is to break the lump talc in a crusher to about $1\frac{1}{2}$ inch size; for this a jaw crusher may be employed. The product then is reduced to one-half of an inch or less in size by rolls, after which it is ready for grinding, which is performed by two stages. In the first a wide choice of apparatus is exemplified by the different plants—the equipment including buhrstones, centrifugal grinders like the Griffen mill and conical pebble mills. The talc is then passed through a bolt of about 60-mesh and is ready

for the finishing or final stage, in which revolving cylinders are used. The Alsing cylinder has the preference in most of the installations, although in the later plants the equipment consists of tube mills. The difference is mainly one of size. The cylinder is from 8 to 10 feet long and 6 feet in diameter, turned 20 to 25 times a minute. It is loaded with 1 ton of talc and 3 tons of pebbles. The grinding operation lasts 2 to 5 hours, depending upon the degree of fineness that is required. The cylinder is idle for the time necessary to charge and discharge it; the tube mill is of the same general pattern as that employed in the reduction of cement materials and its operation does not differ materially in the present case from that in ordinary practice, but the tube must be lined with a material free of iron to prevent contamination. It has a decided advantage over the cylinder in its continuous feed and discharge, but it is not so easily regulated to give the desired finish to the product.

Two tube mills arranged in tandem, so that the discharge of the first goes to the second, may be used for the entire grinding operation, the first mill taking the place of buhrstones or the centrifugal grinder.

The product obtained by grinding of the fibrous talc is an impalpable powder called mineral pulp; under the microscope the particles still show the fibrous texture of the original. For paper filler and for most other purposes uniform fineness is highly desirable. The color should be as nearly dead white as possible; freedom from hard particles like quartz is another factor which is important in grading the talc. The product of the Edwards district is notably free of discoloring impurities and compares favorably with the talc from any other source in that respect. A little grit is present in most of the fibrous talc; less of it in the foliated variety. Unaltered tremolite and quartz are the sources of the grit.

A coarser grade of talc known as buhr stock is made from the fibrous talc by omitting the last stage of grinding in the tube or cylinder mill. This has a distinctly fibrous appearance and feel, the grinding being carried only so far that the material is thoroughly shredded. Buhr stock supplies the place of asbestos in the manufacture of insulating materials.

The ground talc is put up in 50-pound sacks and 200-pound burlap bags for shipment.

Uses. The paper trade is the largest consumer of ground talc, and its requirements have determined more or less the course of technical development in the district. Talc functions as a filler chiefly, but adds other desirable qualities to paper. In its pliancy

and strength talc is superior to most other minerals used for the purpose. The following statement is quoted from an article by J. S. Diller in *Mineral Resources* for 1912. "Talc in paper effects a more uniform distribution of the moisture, improves the polishing, rolling and cutting as well as the strength of the paper." It is certain that a still wider demand for it would develop in the paper trade if a method was found for removing the hard particles which adhere more or less to the talc through all the stages of grinding. One of the main objections to grit is the wear it involves upon certain parts of the paper machinery.

Next to the paper trades, the manufacture of rubber probably consumes the largest amount of ground talc. It is an ingredient of rubber goods of many kinds, in which it may be admixed in large proportions.

The minor uses of talc are legion. It is employed in water-proof paints and distempers; also as an adulterant of metallic pigments in which of course it functions as an inert diluent. Wall-plasters are prepared with coarsely ground fibrous talc in the place of wood, hair or asbestos fiber. It finds employment in the manufacture of cement blocks and artificial stone, for use in electric stations and their equipment, also as an ingredient of the covering of electric wires. When free of iron it is a non-conductor of electricity. It is likewise a good heat insulator and consequently may be employed advantageously for steam pipe and boiler coverings. It is employed in some kinds of glass to give a clouded non-transparent effect. On account of its slippery quality talc makes a useful antifriction substance that is employed in a number of ways, including the lubrication of machinery for which it takes the place of graphite. As an ingredient of foundry facings its smoothness and heat resistance are turned to advantage. Among other uses that may be named are the cotton sizing and bleaching industries, the dressing of leather, fire-proofing of wood and the preparation of cosmetics, and medicinal articles. There are few minerals that compare with talc in its manifold applications and the number of the latter would be greatly increased if recognition were given to the massive variety which is widely employed in an unground state.

Mine developments. Altogether there are nearly 20 mines and prospects in the Edwards district that have engaged attention at one time or another. The greater number of these are in the northeastern section near Talcville. Here are located the mines of the former United States Talc Co., the Uniform Fibrous Talc Co. and some of the properties of the International Pulp Co. In the

middle part of the district near Fullerville is the mine that has been worked until recently by the Ontario Talc Co. who suspended operations with the loss of its mill by fire. On the southwestern end of the district are the Arnold, Wight, Balmat and the property recently prospected by the Dominion Company. The Balmat and Wight mines are operated by the International Pulp Co. who also at one time worked the Arnold mine now held by the Basco Corporation.

One of the principal producers of talc in the district has been No. 2½ mine at Talcville. This is located on a seam of talc which lies on the north side of the limestone belt not far from the granite contact and which has been opened in the United States mine and probably has its continuation in Nos. 3, 4 and 5 mines northeast of Talcville. The mine is opened by an incline shaft which has now reached a depth of over 700 feet on the dip. The seam ranges from 4 or 5 feet to 30 feet in thickness. It starts at the surface with an inclination of 45° northwest and steepens at the 600-foot level to 80° which dip is maintained to the bottom. The body of talc shows numerous rolls and at times pinches down to a narrow seam particularly at the northeast end where the seam swings around to the north probably owing to a fold. On the hanging wall the talc is bordered by hard tremolite schist within which there is more or less talc and this in turn is succeeded by limestone. The granite contact is about 1500 feet distant to the northwest. A considerable flow of water has been encountered in the workings particularly at the 500-foot level. The water seeps in from the walls and along narrow fissures or joints and may come from a considerable distance as it does not seem to be influenced by the changes of level in the river close by. The product of this mine is fibrous stock, with practically no admixture with the foliated variety.

The outcrop of the talc seam disappears a little distance northeast of No. 2½ mine where the ledge is succeeded by an alluvial flat which apparently represents a buried stream channel. Beyond this flat the ledge reappears and has been opened by No. 3 shaft which is not in operation at present but has been a considerable producer of talc in earlier years. Next to this mine is No. 4 which is one of the active properties of the International Pulp Co. This mine is also opened by an incline shaft and has reached a depth of over 400 feet. The levels have an extreme length of 900 feet. Two seams of talc are exposed in this vicinity with a parting of tremolite schist. On the hanging side of the talc is hard schist, then limestone and finally granite. On the footwall of the talc there is in places a soft clayey seam a few inches wide which is soaked with water.

No. 5 mine next northeast to No. 4 has been closed down for several years.

The mine of the Uniform Fibrous Talc Co. is situated just west of Talcville on a slight prominence known as Wintergreen hill. It is opened by a shaft close to the Oswegatchie river. This company began operations in 1911 and the mine is practically a new development from the surface. The deposit appears to be nearly in the same horizon as that defined by the United States and No. 2½ mines at Talcville. The shaft is vertical for the first 90 feet then follows the northwest dip of the talc. The body is said to have a width in places of 30 feet or more and yields a white fibrous talc. The mill is situated close to the mine and both are operated by electric power obtained from the company's hydro-electric station on the west branch, above its junction with the east branch of the Oswegatchie river.

The mine formerly worked by the Ontario Talc Co. is located about 1 mile below Fullerville on the west branch. A shaft follows the seam of talc which dips at an average of 45° northwest and in most parts ranges from 12 to 18 feet in thickness. The talc is mostly of fibrous nature although carrying some of the foliated variety and is of a good white color and soft texture. The foliated talc occurs segregated in bunches and small seams within the main body. On the footwall side the division between the talc and the wall rock is well defined but on the hanging side the talc quite frequently makes off into the country rock and the offshoots when followed may open up into considerable bodies. The product of the mine was ground at a mill situated at Fullerville which was destroyed by fire in the later part of 1917 since which time the mine has been idle.

The Arnold mine in the southwestern section was one of the properties formerly worked by the Union Talc Co. It was later taken over by the International Pulp Co. and in 1917 came under the control of the Basco Corporation which recently entered the district.

The Wight and Balmat mines have been quite actively worked despite their unfavorable situation which necessitates a haulage of several miles to the mills which are situated along the Oswegatchie river. The Balmat mine in fact is one of the principal mines in the district. It is worked through an incline shaft which starts from the surface at an angle of 27° but steepens toward the bottom. The largest levels are about 1000 feet and the seam measures 30 to 40 feet from wall to wall in widest part. On the

hanging side there is from 6 inches to 3 feet of soft foliated talc which in appearance and texture shows strong contrast with the fibrous talc of the main body. This foliated talc is sorted and ground separately, producing a very soft white product which finds special uses.

The holdings of the Dominion Co. join the Balmat mine on the northwest. Some development work has been done on the property, but active production will be postponed until a mill is erected for milling the product.

Natural Bridge. Outside of the Edwards district the only considerable production of talc in recent years has come from the vicinity of Natural Bridge, Lewis county. The St Lawrence Talc Co. has developed a new mine from which it has already produced a considerable tonnage. Natural Bridge lies in an independent belt of the Grenville limestone that parallels the Edwards belt a few miles to the south. The first output was made in the year 1911. The talc from this locality differs from the characteristic Edwards product in that it has a massive appearance, or at most shows a granular habit never fibrous or coarsely foliated. The color of the material mostly is grayish with some greenish inclusions which apparently are in part serpentine and in part a chloritic mineral. Under the microscope the material resolves itself into an aggregate of finely divided scales which are bunched in more or less distinct groups that assume at times a prismatic outline and again are quite irregular. There is some indication of the former presence of amphibole and pyroxene minerals but the alteration to hydro-silicates has proceeded more completely than is usually the case in the Edwards district.

The product of this mine is ground locally in a mill erected by the company for the purpose. The methods of milling are closely similar to those used in the Edwards district. The output of ground talc has been employed to some extent for paper; it is mainly sold, however, for special uses.

References

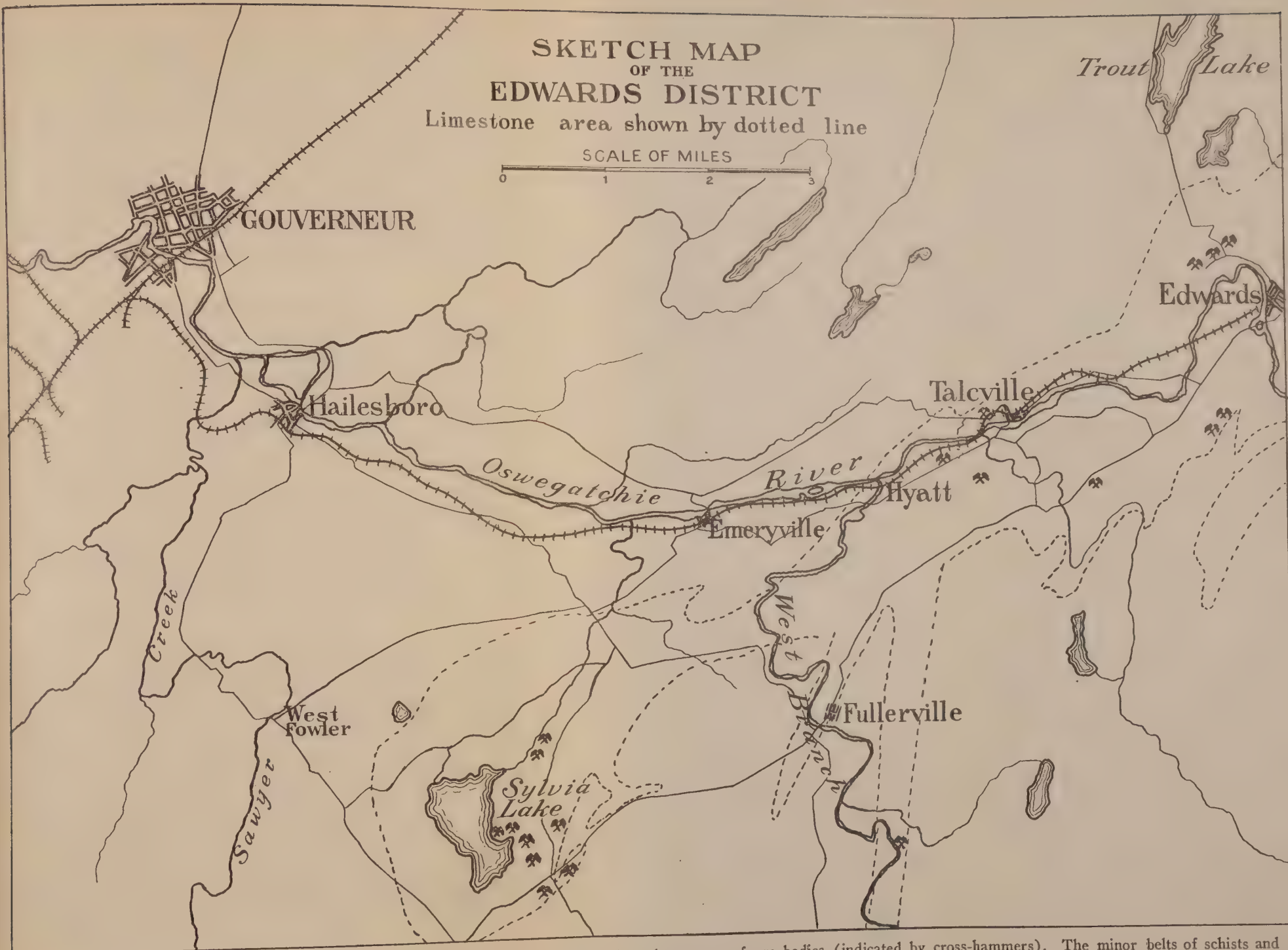
- Brinsmade, Robert E.** Talc in Northern New York. *The Eng. & Min. Jour.*, Dec. 23, 1905
- Diller, J. S.** Talc and Soapstone. *Mineral Resources of the United States*, pt 2, 1912
- Nevius, J. Nelson.** Talc Industry of St Lawrence County, New York. *N. Y. State Mus. Rep't* 51, v. 1, 1899
- Smyth, C. H. jr.,** The Genesis of the Talc Deposits of St Lawrence County, *N. Y. School of Mines Quarterly*, v. 1896, p. 333-41

ZINC

Zinc ores are mined in two separate regions or districts: in the vicinity of Edwards, St Lawrence county, on the west side of the Adirondacks, and in the Shawangunk mountain region of Ulster and Sullivan counties.

The first of these, the Edwards district, began active shipments of blende in 1915 and has been a continuous producer since then, with an annual output which places it among the leading sources of zinc ore in the eastern part of the country. The output so far has been contributed by a single enterprise, the Northern Ore Co., whose property just outside of Edwards village embraces several ore bodies within a single zone of Precambrian (Grenville) limestone. Some 10 or 12 other ore localities are known in the district and the prospects are encouraging that additional undertakings will be established in the near future, as success has already been achieved by the original enterprise. In fact the development of an ore body is now (1918) under way in the vicinity of Talcville, southwest of Edwards by the Dominion Co. of Gouverneur, with such good results that the company looks forward to the inauguration of active mining during the current season and probable production of furnace ore in sufficient quantity to warrant shipment, as the ore contains less pyrite than the average for the district. At Edwards all the mine output is sent to the mill for concentration and separation of the admixed pyrite.

In the Shawangunk region the old mine near Summitville, Sullivan county, was reopened in 1917; a mill was installed on the property and work in the mine carried on for a part of the year. The St Nicholas Zinc Co. is the name of the new enterprise. The mine at Ellenville, 6 miles northeast of Summitville, was unwatered for the purpose of investigation of the possible ores in reserve, but was not put in operation during the year. This property is equipped with mining and milling machinery of quite modern type, as it was worked as late as 1903-4 and the equipment is still on the ground. The mine near Guymard, Orange county, on the southwest end of the Shawangunk range was also under inspection. The workings, which are reached by a vertical shaft 360 feet deep, were drained down to a depth of 165 feet, but as no considerable quantity of ore was found to have been left in the upper stopes, contrary to expectations, the plan of reopening the mine was abandoned after incurring a heavy outlay for equipment. The mine is said to have produced about 10,000 tons of smelting ores (lead and zinc) in the period from 1863 to 1870 when operations were discontinued. The



General sketch of the Edwards zinc district, with outline of the limestone belt and outcrops of ore bodies (indicated by cross-hammers). The minor belts of schists and quartzite within the limestone area are omitted.

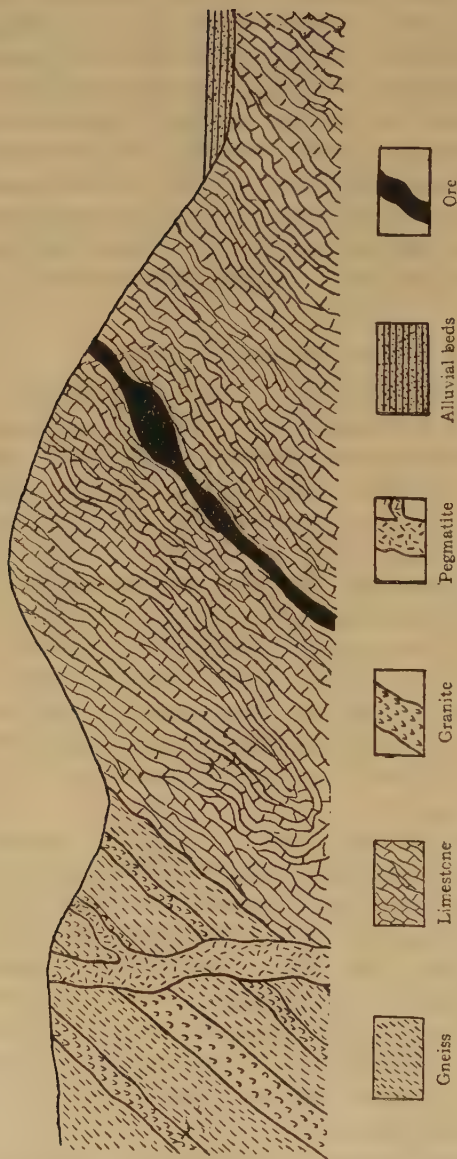
deposit was mined clean, at least to the depth attained in the recent unwatering, and it would appear that the only chance for reviving production lies in the possibility of ore at the bottom, below 360 feet depth. It is of course doubtful if the supply encountered at the bottom would warrant the heavy expense of unwatering and reequipping the property with permanent mine and milling machinery.

A brief resumé of the features relating to the distribution of zinc ores in the State are given herewith. In connection with the Edwards district attention may be called to the recent reports on the geology and economic conditions of the ore occurrence, listed at the end of the chapter; the notes that follow refer more particularly to the later progress of mining developments in the district.

THE EDWARDS DISTRICT

The Northern Ore Co., after 3 years of continuous exploitation of the deposits near Edwards, is increasing its mine and mill equipment. To facilitate the deep development of the ore zone, a vertical shaft has been put down on the hanging side, to the west of the outcrop, which will be used in carrying on operations below the 500-foot level. It has already been carried to a depth of 900 feet, and as soon as connections with the drifts are made will be employed for hoisting. The Williams shaft on the north end has been extended 700 feet along the ore and will soon be in active use. It has been equipped with a new surface plant. This shaft follows an independent ore body, which like those opened to the south is in the nature of a lens or shoot whose longer axis is along the dip. The mill produces both blende and pyrite concentrates, the latter being shipped to acid burners.

The exploration of the Rhodes or Adelbert Freeman farm near Talleville by the Dominion Co. has revealed high-grade ore which is sufficiently free from pyrite to permit its shipment in lump form. The present development is on an isolated ridge which lies within the limestone valley and which is made up of impure limestone, carrying large amounts of serpentine and talc. The exploration of the ore has been carried on mainly through an abandoned talc shaft. From 4 to 6 feet of blende, assaying 42 to 52 per cent zinc, was cut at 75 feet depth. At the surface the ore was about 4 feet thick. Southwest of this locality, about 500 feet across the summit of the hill, a second showing of ore has been uncovered at the surface, but its relation to the first is not yet clear. If it should prove to be a continuation of the same vein the deposit would have the



Geological section at No. 1 mine of the Northern Ore Company, near Edwards

form rather of a vein or a band than the usual lens characteristic of the district. This would also be a favorable condition for mining. In the shoot or lens type of deposit, the levels are short and there is need for constant development to keep the ore supply ahead of the progress of extraction.

The Edwards district represents a type of ore occurrence that is not at all common among the productive mining districts of the country and for that reason the progress of operations has been attended with more than usual interest. In its broader features of geology it finds some analogy in the remarkable occurrence at Franklin Furnace, N. J., inasmuch as the country rocks in both instances are Precambrian metamorphic limestones and the ores themselves seem to have been accumulated in the earliest times. The ores and their immediate mineral associates, however, differ very markedly in the two occurrences and there are other points of contrast that make the comparison of remote value.

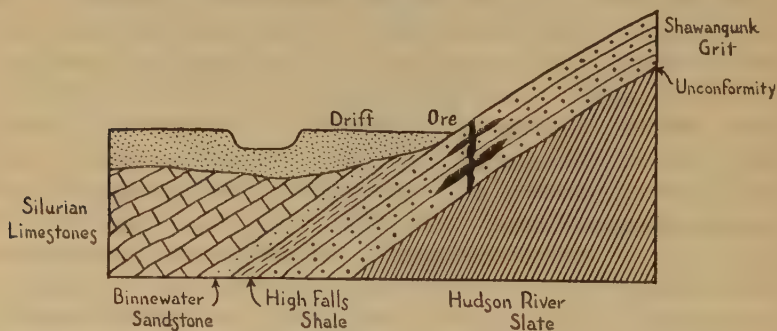
The district proper comprises a belt of crystalline limestone which is partly included within the Gouverneur sheet recently published by the United States Geological Survey, one of the several areas of similar limestones that border the Adirondack highland on the northwest side. The limestone is of early Precambrian age, belonging near the base of this oldest of geological groups and has been thoroughly recrystallized as a result of regional and igneous metamorphism within Precambrian time. The zinc ore is accompanied by many silicate minerals like tremolite, diopside, talc and serpentine, which are directly or indirectly the products of the recrystallization of the calcareous beds and largely formed before the zinc blende itself was introduced. A study of the mineral characters and of the phenomena of the ore deposition has recently been completed by C. H. Smyth jr, and published as part of the investigation of the district conducted by the State Museum (see list of references appended to this article).

It would appear that the explanation of the derivation of the ores most in accord with the observed data involves replacement rather than deposition in open spaces and that this replacement was effected during a period when the limestones were deeply covered, probably by several thousands of feet overlying rock. The agency operative in the process was hot water which carried iron and zinc in solution and as they attacked the limestone and the silicate minerals deposited the metallic sulphides in their place. An invading body of granite, the last of the deep seated magmas that forced its way into the Grenville formations, doubtless had an effective part in stimulating the ore-forming process if it did not

supply the mineralized solutions themselves. The main feature of economic interest in the discussion of origin is that the Edwards ores are not surface accumulations or shallow-vein deposits and that any part of the limestones which have escaped erosion may be considered as possible ore-bearing ground. Thus the progress of mining in depth should not be accompanied by any marked change of character in the ores, or in the possibilities of ore occurrence so long as the limestones themselves continue.

THE SHAWANGUNK ZINC DEPOSITS

The revival of interest in the Shawangunk zinc belt has indicated the need for a study of the ore occurrences of which the only available information is to be found in the brief notes by Mather and Beck included in their reports of 1842 and 1843, at the time the first mining was in progress. It is hoped such study may be undertaken in the near future. Meanwhile, the present account has been prepared from the observations made during a brief visit to some of the recently reopened workings, prompted by the current interest in the subject.



Generalized section across Shawangunk mountain

General features. The Shawangunk mountain is a single ridge which in its development in New York State extends from Port Jervis on the Delaware river northeast to High Falls, 10 miles southwest of Kingston on the Hudson. It is physically a continuation of Kittatinny mountain of New Jersey and Pennsylvania, a part of the Appalachian system. The mountain faces the Catskill plateau from which it is separated by a deep valley that is drained in part by Rondout creek into the Hudson and in part by the Neversink which flows into the Delaware. Its slope on this side

conforms mainly with the dip of a hard quartzite and quartz conglomerate, the Shawangunk grit of Silurian age which disappears in the valley below limestones of the higher Silurian and Devonian formations that likewise are upturned. As Darton states,¹ "The mountain consists of a widely extended sheet of Shawangunk grit lying on soft Hudson River shales. This sheet lies in a gently west dipping monocline which is corrugated by a series of gentle longitudinal folds. To the westward it dips beneath shales and limestones of the succeeding formations in the Rondout valley; to the eastward it is terminated by long lines of high precipices surmounting steep slopes of Hudson river shales." The monoclinical attitude of the formations, as seen from the northwest edge, represents probably the single wing of a broad anticline, of which the larger part has been eroded off, but of which the southeastern limb is found in the Silurian and Devonian strata that reach in a belt from near Cornwall on the Hudson southwest to Greenwood lake and thence into New Jersey. The interval between the two parallel belts is about 20 miles

Nature of deposits. The ores occur in fissures, brecciated zones, and along the bedding planes of the grit. Replacement of the latter by the ore-bearing solutions has taken place only to a very limited extent. The main occurrences are within fracture zones, developed no doubt by shearing and slight faulting of the beds during the uplift which came at the close of the Carboniferous period and resulted in the present folded arrangement. The actual fault displacements are slight but are indicated by the grooving and polishing of the walls of the fissures.

The principal fracturing has been in a plane that crosses the strike of the beds and extends downward at a high or vertical angle. Differential movement, accompanied by fracturing, has taken place also along the bedding planes, and in one instance at least (Summitville) has resulted in a brecciated zone of considerable extent. Secondary alteration as an accompaniment of the fracturing is not marked, although there has been an infiltration of white vein quartz and impregnation of the grit by pyrite before the ore deposition took place.

The ore bodies, as might be expected, are irregular in character, and their size and form are conditioned by the relative degree of fracturing which the wall rock has undergone. In places there has been a minimum of crushing, so that sulphides are restricted to a narrow band or group of individual stringers measured by inches,

¹ N. Y. State Mus. 47th Ann. Rep't, 1894, p. 541.

and again the fracturing may extend over a width of many feet, with a corresponding enlargement of the deposit. The cross-fracture in the Ellenville mine shows extreme variation in this respect, ranging from a few inches to 15 or 30 feet in width. It would appear this quartzite has accommodated itself to stress by irregular, spasmodic movements, indicative of no definite mobility under the conditions, but on the other hand a great resistance to the crushing forces.

The sulphide minerals do not appear to have replaced the quartzite to any extent. The fragments of rock embedded in the ore preserve their singularity and the contact line is abrupt. It is possible that some of the pyrite which occurs in disseminated crystal particles within the quartzite, as well as an ingredient of the ore, may have been deposited by such process, but the main bodies of sulphides bear little evidence of it.

The introduction of the ores was preceded by extensive deposition of quartz, which constitutes the single important gangue material. It is a white or clear vitreous quartz frequently developed in good crystals.

The ore. The metallic minerals are represented by sphalerite, galena, chalcopyrite and pyrite, and most of the ores are mixtures of these different materials. Sphalerite is the most abundant mineral as well as the chief element of value in the ores; but in the early days mining seems to have been directed rather to the extraction and saving of the galena. The latter fluctuates in its proportions and is much more uncertain in its distribution, having a tendency to occur in independent aggregates. Masses of galena are encountered that are practically free of admixture, up to one-half of a ton in weight. Chalcopyrite also varies greatly in its occurrence and seems most abundant in the Ellenville mine, where it forms crystal aggregates in vugs, with vein quartz as a later deposit.

The variation between the different components is so marked that chemical analysis of samples gives little idea of the actual conditions in a large way. Only extensive sampling of the mines or actual runs can supply the basis for estimating the average contents of the ores in the different properties. In the Summitville mine of the St Nicholas Zinc Co. the preliminary sampling, as reported by Mr Kirby Thomas, showed the following percentages:

Iron	3.54
Lead	12.88
Zinc	20.73

Copper was not reported, but it is present in small amount in most samples. Silver was present to the extent of 2.25 ounces to the ton.

The general inference as to the origin of the deposits from consideration of these features is that they were formed by underground circulations directed along the fissure zones and bedding planes of the sandstone. The tendency of the minerals to occur in crystal particles, the frequent occurrence of vugs, and extreme variation in proportions of the metallic ingredients may be noted. The source of the ore-bearing solutions and their character are matters which can not be discussed advantageously at this time. It may be noted, however, that there are no igneous bodies exposed in the vicinity and the only intrusions in southeastern New York that have taken place subsequent to the period of the formation of the sediments is the Triassic trap in Rockland county. The presumption that the waters concerned in the ore-deposition were shallow and supplied from the surface, comparable to the body of underground water in circulation in the beds at present, would seem to be most in accord with the general conditions. However, an interesting observation has recently been communicated to the writer by R. J. Colony with respect to the country rock, who found on examination of the sandstone that it contained secondary minerals, evidencing the effects of metamorphism which are ordinarily ascribed to igneous agencies. The problem requires further investigation before it can be satisfactorily treated.

The question of source of the metals is bound up more or less with the preceding one as to their carrier and solvent agency. Limestones are found to carry zinc and lead and they form the containing rocks for many of the large deposits mined throughout the world. They are more likely to have been the immediate source of the metals than the sandstone. There are two important areas of carbonate rocks in the region, one lying under the valley at the foot of the Shawangunk ridge, and composed of the Helderberg and Onondaga limestones, and the other the belt of Precambrian limestones of which no outcrop is to be seen in the immediate vicinity, but which occur to the southeast in the Wallkill valley as an extension of the New Jersey belts. The former overlie the sandstones and the latter are separated from them by a considerable thickness of shales of the Hudson River group that outcrop on the eastern edge of the ridge and occupy a position below the Shawangunk beds. The nearest exposed area of the Precambrian series is several miles distant, but it is not improbable they may occur in depth within easy reach of the ridge if not actually below it.

If the ore-bearing solutions were surface waters, the Helderberg and Onondaga limestones may well have been the gathering ground and the sources of the metals. In this event the concentration would have been effected by descending waters. The other view of the matter, that the waters came from below, would involve deep-seated circulations and some stimulus in the form of igneous activity, of which there are some indications, as already stated, in the secondary minerals that occur in the sandstones. The evidence in support of either explanation, however, does not suffice at present to form an intelligent opinion in the matter.

The great bodies of zinc ores at Franklin Furnace and Ogdensburg, New Jersey, are some 25 to 30 miles south of the Shawangunk district. They have the Precambrian limestones for wall rocks and have little in common in their mineral features with the present occurrences.

Mining developments. The principal operations in the district of recent date have been carried on at the locality near Summitville, Sullivan county, where mining has been revived in the last year or so by the St Nicholas Zinc Co. The deposit was worked rather extensively between 1830 and 1840, as appears from the description by Mather who refers to the operations at greater length than in reference to the other mines. At that time it was known as the Shawangunk deposit and the lead ore was treated in a local smelter at the foot of the mountain. It consists of a fracture zone, parallel or nearly so to the bedding of the grit, along which has been deposited secondary quartz and sulphides of zinc, lead, copper and iron. The vein appears to conform to the dip of the strata which follows the slope of the mountain but at a higher angle (about 35°). The vein ranges from a few inches to 3 to 4 feet thick. In places it gives an almost solid breast of ore, but ordinarily there is a good deal of rock intermixed.

The present work thus far has been limited practically to the extension laterally of the old openings. These consist of an adit level 220 feet below the outcrop, measured on the vein, and a series of minor levels at intervals to the surface. The main drift measures 400 feet on the course which here is about north-northeast. Enough ore was encountered in the old slopes to sustain operations for the first few months and it was believed by the engineers in charge, that the profits therefrom would repay the costs of the new equipment. The continuation of the ore in depth is the critical circumstance on which the future of the enterprise will depend and there is little in the present conditions on which to base an opinion in regard to the probabilities of the future ore supply.

The ore is brought down to the mill near the base of the ridge by an aerial tramway 1600 feet long. At the mill it is broken in a jaw-crusher and then goes to a ball mill for fine grinding, after which it is sent to a classifier and then passes over Wilfley tables on which the zinc and lead are recovered.

The Ellenville mine is based on a vein in a cross-fracture of the grit. It has been a prolific source of beautifully crystallized specimens of sulphides and quartz which only partly fill the open spaces in the fracture zone. The vein is reached through a shaft near the base of the mountain with levels that extend into the mountain following the course of the vein, which is south 30° east. The dip is nearly vertical. The average width is perhaps 2 or 3 feet but the openings are occasionally 25 or 30 feet across, as stringers of ore make off into the walls along the bedding planes of the sandstone. There seems to be little ore left in the old stopes. The ore carries considerable chalcopyrite as well as galena and blende. According to Mather the mine was opened about 1820 and was in operation in 1840 by the North American Coal & Mining Co. The principal output was in the years 1853-57 when the Ulster Co. worked the property. Operations were resumed for a brief time about 1904-5 by the Ellenville Zinc Co. under whom a milling plant was erected that still stands on the property. In 1917 the Empire State Zinc Co. pumped out the shaft and did some prospecting. A second and parallel fracture zone occurs a little distance to the north which is now utilized by the Sun Ray Spring Co. as a source of mineral water for table purposes. There is an extensive circulation of water along the cross-fractures in the grit.

The Guymard mine, just north of Guymard station and close to the Erie Railroad tracks, is based on a cross-vein in the grit which intersects the ridge in the direction S. 80° E., or about right angles to the strike of the beds. The deposit is said to have been discovered in 1862 and was worked actively from 1863 to 1870 by the Guymard Lead and Zinc Co. which shipped the lead ore to Newark for smelting and utilized the zinc in making zinc oxide. The total ore shipments, lead and zinc, are reported to have amounted to nearly 10,000 tons. The mine was closed after 1870, except for a short period in the eighties. In 1917, Mr K. Farah became interested in the plan of pumping out the workings and reviving mine operations, but after lowering the water down to 165 feet the work was abandoned. Little ore was left behind in the old stopes, and the only possible resource would seem to be on the extension of the vein below the depth obtained in the former operations, which is said to be 350 feet.

The flow of water into the workings is extensive and the cost of pumping out the entire body down to that level would amount to a large sum. Samples of ore taken from the upper levels indicate a high percentage of galena, rather more of it than in the other deposits; but its general appearance otherwise is very similar to that found at the other localities.

North of Guymard, near Otisville is a deposit once worked by the Washington Mining Co. It was prospected in 1906-7 by the Phoenix Lead Co. of Paterson, N. J., but no commercial operations were undertaken. Another locality for the occurrence of these ores is near Spring Glen, described by Mather as "situated on the Shawangunk mountain about one mile east of Redbridge, and six or seven from Wurtsboro; at an elevation of 600 or 700 feet above the valley." Work was carried on by the North American Coal and Mining Co. in 1838 and for sometime afterward, but it is not known what results were obtained.

ZINC IN PALEOZOIC LIMESTONES

A number of localities exist where sphalerite occurs in small amounts in association with bedded limestones, usually as a filling of small solution cavities or occupying joints and narrow fractures that intersect the strata. The Beekmantown and Trenton beds bordering the Adirondacks contain many examples of this association. The gangue is calcite and the blende is frequently accompanied by galena and pyrite. The ore not infrequently shows good values and would repay extraction if obtainable in quantity.

Just west of Saratoga Springs, in an old limestone quarry, a vein of nearly pure sphalerite was to be seen a few years ago. The vein was perhaps 50 to 60 feet long and from a few inches to a foot wide. It was widest in the middle and gradually contracted toward either end, a typical "gash" vein. The sphalerite was of translucent light yellow color, low in iron and unmixed with pyrite.

Near Salisbury Corners is an occurrence of sphalerite in Trenton limestone, filling solution cavities and fissures in the latter. The mineralization is more extensive than in the usual occurrences of the kind. The sphalerite is yellow and translucent to dark opaque and is associated with galena and chalcopyrite with calcite as gangue.

Martinsburg, Lewis county, is listed as a locality for sphalerite with galena and pyrite.

About 2 miles south of Sprakers Basin sphalerite of light yellow color is found in association with galena.

In the Niagara limestone of western New York sphalerite occurs in the lining of small cavities and in stringers, where it is accompanied by galena. The old Pike quarry near Rochester and the quarries near Lockport are localities of such occurrence.

References

- Emmons, Ebenezer.** N. Y. Assembly Doc. No. 200, p. 213, 1838
- McDonald, P. B.** Zinc Mining in New York. Eng. & Min. Jour., v. 95, 1913
- Mather, W. W.** Geology of New York. Report on the First District, p. 358-62, 1843
- Newland, D. H.** The New Zinc Mining District near Edwards, N. Y. Economic Geology, v. 11, 1916
- The Zinc-Pyrite Deposits of the Edwards District, New York. N. Y. State Defense Council Bul. 2, Nov. 1917
- Smyth, C. H. jr.** Genesis of the Zinc Ores of the Edwards District, St Lawrence County, N. Y. N. Y. State Mus. Bul. 201, 1917

INDEX

Abrasive sand, 241
 Abrasives, 219
 Acme Cement Co., 41
 Adirondack province, 14
 Akron Natural Gas Co., 184
 Albany slip clay, 50
 Allegany Pipe Line Co., 205
 Almandite, 16
 Alpha Portland Cement Co., 41
 Alsen's American Portland Cement Works, 41
 American Cement Plaster Co., 100
 American Garnet Co., 83
 American Glue Co., 83
 American Graphite Co., 85, 87, 89
 American Gypsum Co., 100
 Amphibole, 150, 152
 Amphibolite, 122
 Anorthosite, 14, 15, 251, 252, 255
 Apatite, 8, 15, 26-27, 106, 150
 Arsenical ore, 28-29
 Arsenopyrite, 17, 28
 Art wares, 64
 Asbestos, 30-32
 Attica Natural Gas Co., 189

Barium, 20, 218
 Barnum, Richardson & Co., 138
 Barrett Manufacturing Co., 73
 Barton, H. H., & Son Co., 81
 Barytes, 33-35; references, 35
 Barytocelestite, 34, 218, 281
 Basco Corporation, 294
 Becraft limestone, 265, 272
 Bedford Feldspar Co., 76
 Beekmantown limestone, 259, 306
 Bertie waterlime, 96, 99, 172, 225, 226, 263
 Biotite, 149, 151, 152, 153, 154
 Black River formation 173, 259, 260
 Black tourmaline, 153
 Bluestone, 277
 Borst, C. A., 131
 Boulder clay, 52
 Brayman shales, 217, 282

Brick, 51, 52, 54; building, 7, 9-11, 47, 54; ornamental, 47, 49, 52, 54; manufacture, 50, 55
 Brick-making region, 49
 Brockton Gas & Fuel Co., 178
 Buena Vista Oil Co., 205
 Buffalo Cement Co., 166, 181
 Buffalo Natural Gas Co., 181
 Buffalo Pottery, 63
 Building brick, *see* Brick
 Building sand, 235, 236-39
 Building stone, 20, 247, 249, 251, 260, 265, 266, 267, 270, 274
 Building tile, 52
 Burstones, 154

Cady, J. L., 232
 Cady & Johnson, 232
 Cambrian limestones, 259
 Cambrian red slate, 157
 Camillus shale, 96, 225
 Canajoharie shales, 174
 Carbon dioxide, 35-36
 Catlin Oil, Gas & Mineral Co., 194
 Catskill formation, 276
 Catskill series, 158, 197
 Cayuga Lake Cement Corporation, 42
 Cayugan group, 263
 Celestite, 218, 281, 282, 283
 Cement, 37-46; production of, 45; references, 46
 Chalcopyrite, 302
 Chateaugay Ore & Iron Co., 113
 Chazy limestone, 259, 260, 271
 Cheever Iron Ore Co., 110
 Chemical wares, 64
 Chemung formation, 158, 172, 177, 205, 265, 276; thickness, 172
 Chemung group, 52
 Chemung sandstone, 20, 171, 174
 Chemung series, 166
 China, 51
 Chlorite, 213
 Chromite, 25

- Churchville Oil & Natural Gas Co., 191
- Clark Bros. Quarry Co., Fancher, 276
- Clark, Conroy & Co., Norwich, 279
- Claspka Mining Co., 74
- Clay, crude, 8, 9-11
- Clay materials, 47-64; production, 54; references, 64
- Clay products, 7, 9-11
- Clays, 20, 21, 237
- Cleary, John I., Albion, 276
- Clinton formation, 19, 53, 101, 188, 191
- Clinton hematites, 130, 157
- Clinton limestones, 105, 166, 262
- Clinton sandstone, 276
- Clinton shales, 180
- Coal, futility of looking for in New York, 23
- Coastal plain province, 20
- Cobleskill dolomite, 217
- Cobleskill limestone, 263
- Coeymans formation, 265
- Columbia Pipe Line Co., 205
- Conglomerates, 19
- Connor, M. L. & Son, Walton, 278
- Consolidated Rosendale Cement Co., 44
- Copper, 303**
- Core sands, 235, 241
- Corkings, P., 232
- Corniferous limestone, 266
- Cortlandt series, 67
- Corundum, 17
- Crown Point Spar Co., 72
- Crushed stone, 249, 255, 256, 260, 266, 267, 274, 279, 280
- Crystalline limestone, 150, 255, 256-58, 269, 299
- Curbstone, 248, 249
- Dannemora Granite Company, 253**
- Delft, 64
- Deposit Stone Co., 278
- Devonian limestone, 265
- Devonian sandstone, 272, 276
- Diabase, 15, 20, 250, 280
- Diatomaceous earth, 8, 22, 64-66; references, 66
- Diopside, 299
- Dolomites, 255, 258, 271
- Dominion Co., 288, 293, 295, 296, 297
- Dominion Natural Gas Co., 183, 184
- Dover Marble Co., 271
- Drain tile, 47, 51, 52
- Draper & Porter, 232
- Drift, 21
- Drumlins, 21
- Dutchess County Lime Co., 271
- Earthenware, 51, 52, 63**
- Ebsary Gypsum Co., 99
- Electrical supplies, 51, 63
- Ellenville Zinc Co., 305
- Emery, 8, 9-11, 66-69; references, 69
- Emery Pipe Line, 205
- Empire China Works, 63
- Empire Coarse Salt Co., 232
- Empire Gas and Fuel Co., 175
- Empire Gypsum Co., 99
- Empire Portland Cement Co., 40, 192
- Empire State Granite Company, 252
- Empire State Zinc Co., 305
- Enamel ware, 71
- Epidote, 122
- Eupyrchroite, 27
- Eureka Salt Co., Saltvale, 232
- Fair Haven Iron Co., 131**
- Fallkill Iron Co., 125
- Feldspar, 8, 9-11, 15, 17, 69-77, 150, 153, 210, 213; references 76
- Ferro-silicon, 219
- Filter sands, 22, 241
- Fire brick, 47, 49, 52
- Fire sands, 22, 235, 241
- Fireproofing, 47, 51, 52, 59
- Flagstone, 248, 249, 273
- Flake Graphite Co., 89
- Fluorite, 15, 77-78, 150
- Flux, 248, 255, 256, 258, 260, 266
- Fords Brook Pipe Line Co., 205
- Fort Montgomery Iron Corporation, 121
- Franklin Iron Manufacturing Co., 131
- Front brick, 54, 59
- Frost Gas Co., 178

Fuller's earth, 78-79
 Furnace flux, *see* Flux
 Furnaceville Iron Co., 132
Gabbro, 15, 17, 251
 Gale, Thomas K., 232
 Galena, 16, 20, 140, 302, 306
 Garnet, 8, 9-11, 16, 79-85, 152; references, 85
 Gas wells, *see* Natural gas
 Gasoline, 8
 Geddes Coarse Salt Co., 232
 General Electric Co., Schenectady, 63
 Genesee Salt Co., Piffard, 232
 Geological map, 12
 Geology of New York, general feature, 12-22
 Glass, manufacture, 219, 273
 Glass sand, 22, 235, 241
 Glazed brick, 71
 Glens Falls Portland Cement Co., 41
 Gneisses, 17, 104, 210, 215, 217, 255, 271
 Gold sands of the Adirondacks, 24
 Goodwin-Gallagher Sand and Gravel Corporation, 237
 Gouverneur Marble Co., 270
 Graham & Aylesworth, Oxford, 279
 Granite, 8, 9-11, 14, 17, 19, 106, 248, 249, 250-55, 255
 Graphite, 7, 9-11, 16, 85-91, 216; references, 91
 Graphite Products Corporation, 89
 Gravel, 8, 9-11, 21, 225, 235
 Greigsville Mining Co., 223, 228
 Grenville limestone, 105, 255, 256, 270, 295
 Grenville gneiss, 211
 Grenville series, 14, 17
 Guelph dolomite, 262
 Gypsum, 7, 9-11, 20, 91-101, 225, 227; references, 101
 Gypsum belt, map of, 93
Hamilton formation, 276
 Hamilton group, 52, 191
 Hartnagel, C. A., supervision of manuscript and preparation for the press, 5
 Helderberg Cement Co., 41

Helderberg limestone, 303
 Helderbergian group, 265
 Hematite, 16, 19, 101, 105, 126, 156, 157, 213
 Highland Solar Salt Co., 232
 Highlands province, 16
 Hollow blocks, 47, 51, 52, 59
 Hollow tile, 59
 Hoyt limestone, 259
 Hudson River beds, 274
 Hudson River bluestone district, 278
 Hudson River sandstone, 272
 Hudson River shales, 53, 261
 Hudson slate, 18
Igneous rocks, 15
 Ilmenite, 104, 106, 107
 International Agricultural Corporation, 146
 International Pulp Co., 288, 292, 293, 294
 International Salt Co., 232
 Inwood limestone, 258
 Iron mines, map showing location, 134
 Iron ores, 15, 18, 101-40; production, 6, 9-11, 103; distribution, 104; references, 139
 Iroquois China Co., 63
 Iroquois Natural Gas Co., 175
Johnson, P. J., 232
 Johnston & Rhodes Bluestone Co., Horton, 278
Kalkberg limestone, 265
 Kendall Refining Co., of Bradford, Pa., 205
 Kenney Bros., Long Eddy, 278
 Kilpatrick Bros., Hancock, 278
 Kingston Iron Ore Co., 123
 Knickerbocker Portland Cement Co., 41
Lapp Insulator Co., Inc., Leroy, 63
 Lead, 140-43; references, 143
 Lehigh Salt Mining Co., 223, 228
 Leopold, J., & Company, 251
 LeRoy Salt Co., 232
 Leucopyrite, 28

- Lime, 148, 218, 248, 256, 258, 260, 266, 267, 271
 Limestone, 8, 9-11, 15, 17, 18, 19, 104, 133, 158, 247, 248, 249, 255-68
 Limonite, 18, 101, 105, 132, 156, 157
 Little Falls dolomite, 259
 Livonia Salt & Mining Co., 223, 228
 Locke Insulator Manufacturing Co., Victor, 63
 Lockport dolomite, 166, 180, 262
 Lowville formation, 173, 259, 260
 Lycoming Calcining Co., 99
- MacIntyre Iron Co., 115**
 McNierney Bros., Oxford, 279
 Madison Pipe Line Co. of Wells-ville, 205
 Magnesia, 218
 Magnesian limestones, 271
 Magnetites, 15, 17, 101, 104, 105, 109, 120, 152
 Mahopac Iron Ore Co., 124
 Manganese ore, 143-45; references, 145
 Manhattan Trap Rock Co., 280
 Manlius limestone, 263, 264
 Marble, 8, 9-11, 248, 249, 269-72
 Marcellus shale, 20, 160, 171, 172, 176, 180, 189, 191, 226
 Marl, 8, 22, 145-49; references, 148
 Medina sandstone and shale, 20, 53, 166, 168, 171, 172, 176, 178, 179, 180, 183, 185, 186, 188, 189, 190, 191, 192, 272, 274-76
 Metallic paint, 8, 9-11, 157
 Mica, 15, 149-54, 210
 Micanite, 151
 Millen Portland Cement Co., 42
 Millstones, 8, 9-11, 154-56, 221; references, 156
 Mineral industries, value of products, 6
 Mineral paints, 156-58
 Mineral resources, distribution, 12-22
 Mineral water, 8, 9-11, 158-62; references, 162
 Mining in New York State, natural limitations, 23
 Mohegan granite, 67, 253
 Mohegan Granite Company, 253
- Molding sand, 8, 9-11, 235, 239-40
 Molybdenite, 15, 163-65
 Monumental stone, 248, 249, 251, 252, 270
 Moore & Waite, 276
 Mount Summit Ore Corporation, 123
 Muscovite, 149, 151, 152, 153, 154
- Natural cement, 8, 9-11, 42-46, 263**
 Natural gas, 7, 9-11, 20, 165-97; references, 197
 New Scotland formation, 265
 New York and New England Cement & Lime Co., 41
 New York Central Gas Co., 188, 189
 New York Fuller's Earth Co., 78
 New York Pyrites Company, 212
 New York Transit Co., Olean, 205
 Newman, H. L. & W. C., 45
 Niagara dolomite, 275
 Niagara Gypsum Co., 100
 Niagara horizon, 179, 188
 Niagara limestone, 307
 North American Coal & Mining Co., 305
 North River Garnet Company, 16, 81
 Northern Ore Co., 296, 297, 298
- O'Brien Brothers, Inc., Hempstead, 237**
 Ocher, 158
 Olean conglomerate, 18
 Oliver Mining Co., 108, 211
 Onondaga Coarse Salt Association, 232
 Onondaga limestone, 20, 159, 171, 172, 176, 180, 185, 189, 191, 226, 264, 265, 266, 303; thickness, 266
 Onondaga Pottery Co., 63
 Onondaga salt group, 225
 Ontario Gas Co., 190
 Ontario Iron Co., 132
 Ontario Talc Co., 293
 Opalescent glass, 71
 Ophealcite, 269, 270
 Orchard Park Oil & Gas Co., 185
 Ordovician limestone, 259-62
 Oriskany sandstone, 172, 220
 Orleans County Quarry Co., 276

Orleans Sandstone Co., Holley, 276
 Orpiment, 28
 Oswego sandstone, 173, 192

Paints, 219

Paleozoic province, interior, 18
 Palisades, 12, 20
 Pamela limestone, 260
 Paper, talc used in making, 291
 Parrott Iron Co., 119
 Pass & Seymour, Inc., Syracuse, 63
 Pavilion Natural Gas Co., 188
 Paving blocks, 248, 251, 279
 Paving brick, 47, 51, 52, 54, 60
 Peat, 8, 22, 197-202; references, 202
 Pegmatites, 17, 69, 122, 150, 153, 154, 253
 Petroleum, 7, 9-11, 20, 203-9; references, 209
 Phlogopite, 149, 150, 151, 153, 154
 Phoenix Lead Co., Patterson, N. J., 306
 Phoenix Sand and Gravel Co., Roslyn, 237
 Picton Island Red Granite Company, 251
 Platinum, 25
 Pleistocene and recent formations, 21
 Polishing sand, 235
 Pope Mills Graphite Co., 90
 Porcelain electric supplies, 51, 63
 Port Henry Iron Ore Co., 108
 Portage formation, 177, 265, 276
 Portage group, 52
 Portage sandstone, 20, 171
 Portage strata, 172
 Portland cement, 7, 9-11, 37-42, 45, 94, 148, 260, 267
 Potash, 8
 Potsdam Red Sandstone Co., 273
 Potsdam sandstone, 18, 193, 220, 272
 Pottery, 7, 9-11, 47, 52, 54, 63, 219
 Poughquag quartzite, 221
 Precious metals, not present in New York in workable quantity, 24
 Pressed brick, 52
 Producers Gas Co., 175
 Putnam County Mining Corporation, 28

Pyrite, 6, 9-11, 16, 20, 124, 129, 209-18, 302, 306; references, 218
 Pyroxene, 150, 152
 Pyroxenite, 17
 Pyrrhotite, 16, 17, 210, 212, 215, 216, 217

Quartz, 8, 9-11, 15, 17, 150, 210, 213, 218-21

Quartzite, 17, 219, 220, 273

Reed, Allen & Reed, 276

Remington Salt Co., Ithaca, 232
 Retsof Mining Co., 223, 228, 229
 Reynolds, William J., Roscoe, 278
 Riprap, 248
 Rock Glen Salt Co., 232
 Rock salt, 20, 96, 222, 225
 Rock Salt Corporation at Portland Point, 223, 228
 Rondout waterlime, 263, 282
 Roofing slate, 18, 157
 Rosendale cement, 37
 Rossie Iron Ore Co., 128
 Rubber, manufacture, 292
 Rubble, 248, 274
 Ryan, M. A., 276

St Lawrence Pyrites Company, 212, 215

St Lawrence quarries, 270
 St Lawrence Talc Co., 295
 St Nicholas Zinc Co., 296, 302, 304
 Salina beds, 225
 Salina belt, 227
 Salina formation, 20, 53, 96, 190, 263
 Salina series, 172
 Salina Solar Coarse Salt Co., 232
 Salina waterlime, 20, 171, 180, 185, 189

Salt, 7, 9-11, 20, 221-35; historical, 222; occurrence, 223; map of district, 224; manufacture from brine, 229; production, 232; references, 234

Salt Springs Solar Coarse Salt Co., 232

Sand, 8, 9-11, 20, 21, 225, 235-42; references, 242

Sand-lime brick, 8, 9-11
 Sandstone, 8, 9-11, 19, 220, 247, 248, 249, 272-81
 Sanitary wares, 64
 Schists, 16, 18, 105, 210, 215, 271
 Scorodite, 28
 Series of New York formation in order of occurrence, table, 13
 Serpentine, 30, 139, 270, 272, 299
 Serpentine marble, 269
 Sewer pipe, 47
 Shale, 19, 217
 Shaw, Herbert, Middletown, 278
 Shawangunk grit or conglomerate, 154, 220, 235, 272, 276
 Shawangunk zinc belt, 300
 Siderite, 18, 101, 105, 133
 Sienna, 158
 Silicon, 219
 Silurian strata, diagram indicating position, 95
 Silver, 303; in galena, 25
 Silver Creek Gas & Improvement Co., 178
 Slate, 8, 9-11, 18, 105, 242-47; references, 247
 Slate pigments, 157
 Slip clay, 50
 Solvay Process Co., 42, 223, 232, 267
 South Buffalo Natural Gas Co., 166
 South Shore Natural Gas Co., 178, 179
 Sphalerite, 16, 20, 302, 306, 307
 Sterling Salt Co., 223, 228, 229
 Stone, 8, 9-11, 247-50; references, 281
 Stoneware, 50, 63
 Stoneware clay, 51
 Storm King granite gneiss, 17
 Strontianite, 281, 282
 Strontium, 20, 218, 281-83
 Sun Ray Spring Co., 305
 Syenite, 14, 106, 251, 252
 Syracuse Pottery, 63

Tables, mineral production of New York, 9-11; series of New York formations, 13; manufacturers of natural cement, 44, 45; cement, 46; analysis of shales, 53; building

brick, 56; output of common brick in Hudson River region, 57-58; emery, 67; feldspar and quartz, 72; garnet, 84; gypsum, 92; analyses of New York gypsum, 98; iron ore, 103; millstones, 156; natural gas, 169; petroleum, 203; salt, 232; sand and gravel, 242; slate, 246; stone, 248-50; analyses of limestones, 257, 258-68; talc, 285; analyses of talc, 286

Taconic province, 17

Talc, 7, 9-11, 16, 283-95, 299; references, 295

Terra cotta, 47, 49, 54, 71

Terra cotta lumber, 59

Thomas Iron Co., 123

Tide Water Pipe Co., 205

Tilly Foster Iron Co., 124

Titanite, 150

Titanium, 17

Tobacco pipes, 64

Tourmaline, 150

Trap, 8, 9-11, 20, 248, 249, 250, 279-81

Travis Stone Co., 278

Tremolite, 299

Trenton limestone, 20, 159, 168, 171, 173, 180, 192, 193, 196, 259, 260, 261, 271, 306

Triassic sandstone, 279

Tribes Hill limestone, 259

Tri-County Natural Gas Co., 189

Tripoli, 64

Tully limestone, 226, 227, 265, 267

Turk's Island Coarse Salt Co., 232

Uniform Fibrous Talc Co., 288, 292, 294

Union Pipe Line Co., 205

Union Porcelain Works, Brooklyn, 63

United States Gypsum Co., 100

United States Talc Co., 292

Vacuum Oil Co., Rochester, 205

Verd antique, 269, 270

Vernon shales, 96, 158, 225, 226

Vincelli, Thomas, Hulberton, 276

Vincent Stone Co., 276

Wallkill Portland Cement Co., 39
Wappinger limestone, 18
Warren County Garnet Mills, 81
Watkins Salt Co., 232
Wayne Iron Ore Co., 132
Weber Electric Co., 63
Wernerite, 150
Western Coarse Salt Co., 232
Whirlpool sandstone, 173
White, John, & Son, 232
White Crystal Marble Co., 270
Wisconsin Granite Company, 251

Witherbee, Sherman & Co., 26, 108,
110, 111
Wolcott limestone, 188
Wood-filler, 219
Worcester Salt Co., 232

Yonkers gneiss, 253

Zinc, 23, 296-307; references, 307
Zinc ore, production, 6, 9-11
Zinc-pyrite, 16

RES. FAC.	8	4	2	1	36	35	34	33
MISC. CODE				C 58845ER				
Q	New York. State Museum,							
11	Albany							
N82	no.223-224 Bulletin							
8	NAME & ADDRESS				IDENTIFICATION NUMBER			
7	BINDERY							
6	MAY 15 '67 UIC							
5								
4								
3								
2								
1								

Q
11
N82 New York. State Museum, Albany
no.223-224
Bulletin



